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An Attempt to Identify Indicators of Competence on Mechanical Maintenance Tasks

by

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Prepared for

U.S. Army Research Institute for the
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Army service schools are often faced with the problem of evaluating student performance on job tasks that are extremely time consuming or resource constrained. Solutions may lead to methods of testing in which students are tested on parts of tasks only. Methods of part-task testing are useful only if the sample of task elements comprising the test are predictive of whole-task proficiency.

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The work reported describes attempts to develop procedures that enable test developers to identify elements that predict task performance. One approach follows closely the task analysis review procedure used in skill qualification test development. Another requires subject matter experts to select task elements to test, given specific selection criteria. In a third approach, performance data from an Army training study were examined to determine empirically the most likely testing point(s) within each of the tasks tested.

Results of the research indicate that the identification of task-element samples predictive of whole-task performance is a problem not easily solved. Subject matter experts did not agree well in their selection of most-predictive elements, and an empirical study of existing performance data indicated that most-predictive elements have little in common even among similar tasks. Until particular types of elements can be verified as predictive of performance for particular types of tasks, procedures for part-task test development cannot be set forth. Future approaches to identifying and classifying predictive task elements should be based on experimentally generated performance data supported by comprehensive diagnostic scoring.

PREFACE

Work reported here was conducted by the Human Resources Research Organization (HumRRO) under Contract No. DAHC 19-78-C-0024 with the U.S. Army Research Institute. The report covers approaches to develop procedures that enable test developers to select subsets of task elements predictive of whole task performance and to convert the subsets into efficient group tests.

The research was performed at HumRRO Western Division, Radcliff, Kentucky, where Mr. William C. Osborn is the Office Director. Charlotte H. Campbell, James H. Harris, and William C. Osborn performed the work reported.

SUMMARY

This report describes approaches taken to develop procedures that enable test developers to identify elements of tasks that predict overall task performance.

REQUIREMENT

The requirement to which this work was addressed was to develop an economical method for drawing valid inferences about a soldier's ability to perform the tasks on which he has been trained. The project had two objectives. The first objective, related to the key problem in developing economical proficiency tests, was to develop procedures for identifying elements of tasks that predict overall task performance. The second objective, predicated on the success of systematically identifying the predictive elements, related to developing a technique for constructing reliable, valid, feasible, and acceptable hands-on tests for the subsets. The specific objective was to develop procedures for constructing "less than full" hands-on tests that yield individual scores.

PROCEDURES AND RESULTS

Three approaches were taken to meet the first objective of the project; that is, selecting subsets that predict overall task performance. The first approach follows closely the task analysis review procedure developed for the skill qualification test workshops, with changes made to reflect group or expensive individual tasks. The intent was for subject matter experts to identify task elements that were likely candidates for testing and then verify the identifications by having soldiers perform the tasks reviewed and comparing their performance with the predictions. For a variety of reasons, the verification did not proceed as planned. Essentially, each task took so long to perform, at least for soldiers at the entry-level of experience, that there was neither the time nor the equipment available to conduct the verification. For this reason, a second approach was taken to develop procedures that would enable test developers to identify predictive elements systematically.

A set of performance data from an Army training study (ARTS) was used to verify selection procedures. The plan was to develop a selection instrument and have subject matter experts select elements to test. If the inter-judge agreement levels were satisfactory, the selections could be compared with available performance results on the large sample of soldiers. In order for the selection procedures to be systematic and useful for test developers, they must work as well with one subject matter expert as with another. High agreement

would indicate that having one person select elements would be as valid as collecting the same information from any other, or from a group, with a considerable savings in time and effort. Inter-judge agreement levels were too low to warrant use of the selection procedures in test development.

In the third approach, task performance data were examined to determine empirically the most likely testing point(s) within each task. Based on the results of the empirical examination, procedures could be established for test developers to select these same testing points without benefit of test results. A forward (stepwise) multiple regression and a Guttman scalogram analysis were performed on the data to determine if a) a subset of elements could be identified for each task which were predictive of whole task performance, and b) the elements comprising a task were unidimensional and of incremental difficulty. The results of the statistical analyses indicate that the most predictive elements could be identified empirically. The problem is that the most predictive elements in the array, whether evaluated within each task, over all tasks, or within a task category, seem to have nothing in common.

It was recommended that future approaches to identifying and classifying predictive task elements be based on experimentally generated performance data supported by comprehensive diagnostic scoring. It was noted, however, that if underlying sources of task element commonality are found, they may be of no use in test developmemt. For example, the most-predictive elements may be those that are not covered in training, or those that cannot be observed, or those that are the least well described in the job aid.

USE OF FINDINGS

Since results of this work indicate that extreme caution should be exercised in attempting to develop a performance test covering a sample of task elements only, the report should be of interest to test developers throughout the Army's service schools.

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CHAPTER 1

INTRODUCTION

BACKGROUND

One responsibility of Army service schools is to certify trainee proficiency. The developer of training certification tests shares the dilemma of those involved in all applications of proficiency measurement: achieving a balance between test quality and administration economy.[1] To achieve some perspective on the problem of balancing quality and economy, consider first, that a full performance test (demonstration of the actual criterion behavior in a realistic criterion setting) is the most valid type of proficiency test, and second, that a group administerable test yielding scorable task product and process scores for individuals is the most feasible type of proficiency test. Any test, then, that is both full performance and group administerable--valid and feasible--is an efficient test and should present no problem to the developer or administrator. The balance is difficult to achieve at most Army service schools where budgetary constraints force test developers to confront the problems of equipment availability, scorer qualifications, and time limitations.

These confrontations cause severe problems for the schools' quality control systems. Each school has a quality control system based on comprehensive performance tests. Since the most clearly valid form of performance test is the hands-on test, service schools have constructed hands-on tests for most MOS producing courses. The tests have two purposes: to provide feedback on the quality of training and to certify whether trainees are able to perform the tasks addressed in training.

The most common problem with this approach is that there are too many tasks to conduct a hands-on test for each trainee on each task. Trainers compromise by testing a sample of tasks. The sample consists of the most "critical" tasks, which are tested each cycle, and a random sample of the remaining tasks. This compromise reduces the ability to certify trainees on the complete job, but if all tasks are eventually tested, retains the feedback to trainers on the quality of training. At least it appears to in theory.

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[1]Osborn, W.C. An Approach to the Development of Synthetic Performance Tests for Use in Training Evaluation. HumRRO Professional Paper 30-70, December 1970.

In reality, many schools do not vary the tasks tested in such a way to assure that all tasks are eventually tested. Varying the sample entails requesting new equipment, modifying the test area, formalizing the test instrument, and training new scorers. The first sample tends to be the only sample.

Trainers thus must draw inferences from a sample of behavior to evaluate a larger class of behavior. But since the tasks are not selected systematically, many service school test programs are sufficient neither for training feedback nor for individual certification. In this way, test quality and administration economy get out of balance.

If the schools' quality control systems are to be credible, they must either reduce the scope of training or confront the issue of administration economy. Since most schools will still train too many tasks to conduct a hands-on test for each soldier on each task, some compromises will be required to maintain an acceptable balance between test quality and administration economy. The purpose of the work reported here was to provide a basis for compromises to maintain the balance for at least some of the tasks taught at service schools.

PROBLEM

One aspect of performance testing that is important at some service schools is testing tasks in student groups. Hands-on tests for groups cover two types of tasks:

1. Group tasks which are normally, and often necessarily, performed on the job by a team or crew. This type of task is rarely addressed in service school training or testing.

2. Individual tasks which require so much time or equipment that the only economical method of testing is with a group of soldiers. Each soldier performs only a part of the task, working simultaneously with others on different components of the equipment, or in circuit on the same part of the equipment. Strictly speaking, these are not group tasks, but the requirements for training and testing are so extensive that in the school setting they are performed by groups.

If tests were needed only to provide feedback on the quality of training, group testing would pose only minor problems. Trainers could simply test examinees as a group and draw inferences concerning full task training from the performance of the group as a whole. Unless the part-task performed by an individual is representative of the whole task however, part-task test results are not suitable for certifying individual trainees as proficient on the whole task. The approach of group testing on random part-tasks is a microcosm of end-of-cycle tests--trainers must draw inferences from a sample of behavior (part-tasks) to evaluate a larger class of behavior (whole tasks) even though the sample is not selected systematically.

Trainers have another alternative for group testing that increases both the quality and cost of the test. This alternative is to test each soldier in each duty position. For example, if one soldier operates a hoist while a second guides a power pack into position and a third soldier connects the pack, trainers could test the group three times, rotating soldiers through each position. The information would be better than a test of random samples of part-tasks, but the increase in cost would outweigh the increase in quality to the point where there is no savings over a full task test for each soldier. Even if service schools did not face major time, personnel, and equipment constraints, the improvement in test quality is more apparent than real. The validity of this test approach is reduced by two factors that compromise test standardization:

1. The learning effect that occurs for part-task X while performing part-task Y is not controlled.

2. Since the quality of performance of others in the group is not controlled, a given soldier's proficiency is subject to measurement error resulting from unstandardized test conditions.

Not all Army service schools train tasks which require group testing. But when a school does address this type of group task, the tasks are usually at the heart of the school's training mission. If they are to have an efficient quality control system, they need an economical method to certify trainee proficiency on such group tasks.

A POSSIBLE SOLUTION

Individual hands-on tests, even part-task tests, are usually easier to score and more obviously fair than group tests since everyone faces the same requirements. But a group test that results in individual scores is the most efficient method for testing expensive individual tasks. Thus, a likely approach would be to develop "less than full-performance" tests on a sample of a trainee's task performance. Since a sample of performance was proposed, the most efficient sample would be one that included only those task elements that are the most predictive of whole task proficiency. Each soldier would perform a subset of the task and his performance on the assigned subset would be the basis for his score. The tests would have to meet three criteria:

1. Each examinee would be required to demonstrate the same types of behaviors as would be required on a full performance test.

2. The tests could be administered to a group of examinees.

3. The tests would result in individual scores.

The success of this approach hinged on developing a methodology to identify elements of tasks predictive of overall task performance. If predictive elements could be identified systematically, procedures could be developed to enable Army service school test developers to select the elements and convert them into efficient group tests.

OBJECTIVE

The project originally had two objectives. The first related to the key problem in developing "less than full-performance" tests that yield individual scores. The objective was:

- To develop procedures for identifying elements of tasks that predict overall task performance.

The second objective, predicated on the success of systematically identifying the predictive elements, related to developing a technique for constructing reliable, valid, feasible, and acceptable hands-on tests for the subsets. The specific objective was:

- To develop procedures for constructing "less than full-performance" hands-on tests that yield individual scores.

As indicated, work on the second objective depended on accomplishing the first. And since, despite our efforts, procedures for identifying predictive task elements could not be validated, there was no basis for undertaking development of test construction guidance to use the procedures.

OVERVIEW

This report documents attempts to identify elements of mechanical maintenance tasks predictive of overall task performance. The research evolved--largely because of practical limitations on data collection--into three phases. These phases are reported as Studies I, II, and III.

The primary purpose of the project was to develop a set of procedures which would enable test developers to identify task elements that predict successful task performance. Since test development normally begins with a review of the task analysis data, the most logical approach was to tie the identification procedures into the task analysis review phase. Because task analysis data must often be modified by the test developer when the data are to be used as a basis for test construction, no new step would be added to the test development cycle; changes would be made to an existing one. Therefore, in Study I procedures were developed by which test developers would have subject matter experts (SME) review and modify task analysis data. The procedures were to serve two purposes. First, they would insure the task analysis data were at a level of detail sufficient to be useful for test construction. Second, the procedures would enable test developers to identify task elements that were likely candidates for testing; that is, those elements whose successful performance predicts overall task performance. These identifications were to be verified by having soldiers perform the tasks reviewed and comparing their performance with test developer predictions.

Since the data from Study I did not confirm the usefulness of task analytic data in revealing predictive elements for part-task testing, another approach was tried in Study II in which subject matter experts directly nominated task elements for testing according to prescribed criteria. Results of the second study were also inconclusive. In Study III the judgment of subject matter experts was circumvented altogether and task elements were explored empirically in an effort to identify from actual test results those elements predictive of whole task performance.

Data in all studies pertained to the heavy equipment maintenance field--63H10 automotive maintenance, 45L10 artillery maintenance, and 63C10 tracked vehicle maintenance--since job tasks in this field are typically difficult to test efficiently.

The method, results, and discussion of each of the three studies follow. A discussion of the research in terms of "lessons learned" and implications for future work concludes the report.

CHAPTER 2

STUDY I: IDENTIFYING PREDICTIVE ELEMENTS FROM SME TASK ANALYSIS REVIEW

The first study was conducted according to the original plan of research. Its intent was to develop and validate procedures for test developers to review and modify task analysis data for use in part-task development. The approach was based on task analysis review procedures for SQT development with changes made to reflect the concern of the research with group or expensive individual tasks.

METHOD

Two activities were performed to develop a procedure that test developers could use to review and modify task analysis data. The two activities were 1) development of task analysis review and modification procedures, and 2) conduct of task analysis review.

Task Analysis Review and Modification Procedures

Test developers must follow a logical review process in order to identify, as early as possible, information gaps in the existing task analysis data.[1] The procedure consists of seven steps or items to provide test construction information. The questionnaire developed for task analysis review and modification is presented at Appendix A.

Because mechanical maintenance tasks contain so many performance elements, the procedure begins with an item to reduce the number of elements a reviewer has to consider during the review of any task. Item 1 enables the reviewer to identify any subtasks within the task being reviewed and then to continue the review procedure for each of the subtasks. For example, eight subtasks were identified for the task, "Replace transmission 5-ton, M813." The eight subtasks are:

1. Disconnect power take-off shaft and PTO linkage.

2. Remove transmission.

3. Remove clutch assembly.

4. Test and adjust clutch assembly and inspect pressure plate for warpage.

5. Install clutch assembly.

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[1]Campbell, R.C., Ford, P., and Campbell, C.H. Development of a Workshop on Construction and Validation of Skill Qualification Tests. HumRRO Final Report FR-WD(KY)-78-2, March 1978.

6. Install transmission.

7. Connect power take-off shaft and PTO linkage.

8. Adjust clutch linkage and free travel.

Each subtask defines an action that has a measurable outcome. The instructions tell the reviewer to continue the review procedure with the first subtask, then repeat the review procedure for the remaining subtasks identified in Item 1.

The purpose of Item 2 is to determine if the subtask might be performed under different conditions and if so, whether the subtask is then performed differently. Changed conditions sometimes alter the elements in task performance and sometimes make the task more or less difficult. For example, removing the transmission on a 5-ton, M813 is more difficult when done outdoors in the rain than when done in a maintenance shop.

The third item is necessary to account for the inclusion of all task elements. Here, the reviewer adds elements to permit identification of correct performance, deletes elements not needed to identify correct performance, or revises elements to permit identification of correct performance by defining observable actions.

The fourth and fifth items begin the identification of task elements that are likely candidates for testing. Reviewers are first asked to identify the most common sources of failure in subtask performance. The most common mistakes in a procedure are usually the best predictors of overall performance. The fifth item addresses the issue of criticality. The intent of the item is to assure that the most important elements are tested even though they may not be sources of frequent errors. Here, most safety procedures, elements that can cause the system to fail, and elements that are not detected by checks in the system, are included. Although these elements may not be as predictive as frequent sources of error, they must be included for the test to be a credible check on the quality of training.

The necessity of performing any of the task elements in sequence is determined in Item 6. This does not include elements which are sequential because of equipment design; for example, on the 5-ton, M813, the transmission must be removed before the clutch assembly can be removed. It does include, for the task, "Replace 5-ton, M813 transmission," performing all the elements regarding connecting heavy lifting device and absorbing weight of transmission before removing last two capscrews and lockwashers securing clutch housing to flywheel housing.

The final item (Item 7) identifies time constraints for any element(s) and the consequences of failing to perform the element(s) within that time.

Task Analysis Review

Three tasks were selected for task analysis review and modification. The three tasks were:

1. Borescope and pullover gage cannon tubes (MOS 45L10, Artillery Repair).

2. Inspect declutching feed mecahnism (MOS 45L10, Artillery Repair).

3. Replace transmission, 5-ton, M813 (MOS 63H10, Automotive Repair).

These tasks were selected because they were each group trained and group tested, and they each took more than one hour to perform.

The task analysis review was conducted by members of the project staff with SME from the Ordnance School. Four SME reviewed each task. For the two 45L10 tasks, the SME were two civilian instructors and two E-7 instructors. The review procedure for each of the two 45L10 Artillery Repair tasks was as follows:

- The SME panel was convened and each item in the questionnaire (Appendix A) was discussed with each SME. All SME responses were recorded. The panel format was used to have more control over the review during the initial tryout.

- The individual SME responses were discussed and consensus answers reached for each item.

- The task was performed in its entirety by a member of the project staff. The task was performed for three reasons: first, to enable the staff member to learn how to perform the task; second, to assess the adequacy of the reference materials available to the soldier when he performs the task; and, third, to assess the adequacy of the task analysis.

The 63H10 task was reviewed by three people from the mobility branch of the Ordnance School; one was the Branch Chief (a warrant officer), one was an E-6 instructor, and one was an E-5 instructor. The fourth 63H10 reviewer was an E-6 from the task analysis branch of the Directorate of Training. The procedure for reviewing the 63H10 automotive repair task was reversed; that is, a member of the project staff performed the task in its entirety and then discussed the Task Analysis Review and Modification questionnaire with the four SME. The procedure was reversed to make the discussion of the task more beneficial since the "test developer" (in this case, a member of the project staff) would be more familiar with the task.

RESULTS

The results of the review and modification are presented (Tables 1, 2, and 3) for selected items on the questionnaire. Additionally, the complete revised task analysis for the 63H10 automotive repair task is presented at Appendix B. The subtasks identified for each task are listed in Table 1. Each subtask can stand on its own as a separate task with a measurable outcome. Changed conditions do not alter the elements for any of the three tasks (Item 2 in the Task Analysis Review and Modification). The ease with which parts are removed and replaced, of course, varies with the condition (e.g., rusty, not rusty; new, old) of the parts.

The common sources of error in tasks are shown in Table 2. These are the elements which panel members indicated are most often performed wrong or not performed; they make up what would be the most difficult items. Included among the "difficult" items are such elements as:

- Select wrong pullover gage stop (Borescope and pullover gage cannon tubes).

- Put declutching feed mechanism torsion spring in backwards (Inspect declutching feed mechanism).

- Leave shipping bolts in 5-ton, M813 clutch pressure plate assembly (Replace transmission, 5-ton, M813).

The elements which can result in serious consequences if not performed correctly (or not performed) are given in Table 3. The intent, again, was to assure that the most critical elements emerged as candidates for testing. Critical elements include:

- Identify defects which condemn cannon tube (Borescope and pullover gage cannon tubes).

- Time gun to declutching feeder (Inspect declutching feed mechanism).

- Adjust 5-ton, M813 clutch linkage (Replace transmission, 5-ton, M813).

On the revised task analysis for the task, "Replace transmission" (Appendix B), the critical and difficult elements are marked with an asterisk (*). Those elements which must be performed in sequence for reasons other than equipment design are indicated in the task analysis (Appendix B) by a double asterisk (**). There were no time constraints for performing any element(s) among the three tasks reviewed.

Table 1

Subtasks Identified for Each Task Reviewed and Modified

(Item 1)

Task	Subtasks
45L10 Borescope and pullover gage cannon tubes	1. Set up borescope. 2. Borescope cannon tube. 3. Take down borescope. 4. Determine if cannon tube is required to be pullover gaged. 5. Set up pullover gage. 6. Pullover gage cannon tube. 7. Complete DA Forms 2404, 2407, 2408-4.
45L10 Inspect declutching feed mechanism	1. Remove mechanism from 20mm cannon. 2. Inspect mechanism before disassembly. 3. Disassemble mechanism. 4. Clean mechanism. 5. Inspect mechanism after disassembly. 6. Assemble and time mechanism. 7. Test mechanism for wear and warp (operational check). 8. Install mechanism on 20mm cannon.
63H10 Replace transmission, 5-ton, M813	1. Disconnect power take-off shaft and PTO linkage. 2. Remove transmission. 3. Remove clutch assembly. 4. Test and adjust clutch assembly and inspect for warpage. 5. Install clutch assembly. 6. Install transmission. 7. Connect power take-off shaft and PTO linkage. 8. Adjust clutch linkage and free travel.

Table 2

Common Sources of Error (Most Difficult Elements) in Tasks

(Item 4)

	Task	Number of Elements	Number of Common Sources of Error	Examples of Common Sources of Error
45L10	Borescope and pullover gage cannon tubes	66	10	. Line up reference line with illuminating head mirror. *. Identify defects which condemn cannon tube. . Select wrong pullover gage stop. . Stop pullover gage before reaching breech face of cannon tube.
45L10	Inspect declutching feed mechanism	98	5	. Remove end play of drive shaft . Depress actuating shaft when installing and timing end drive assembly. . Put torsion spring in backwards
63H10	Replace transmission, 5-ton, M813	79	8	. Leave shipping bolts in clutch pressure plate assembly. . Leave grease on face of clutch pressure plate assembly. . Put lubricant in transmission.

*Also identified as a critical element.

Table 3

Elements Which Can Result in Serious Consequences
If Not Performed Correctly

(Item 5)

TASK: Borescope and pullover gage cannon tubes (45L10)

ELEMENTS:
*. Identify defects which condemn cannon tubes.
. Measure bore width correctly.
. Read bore width measurement correctly.
. Select appropriate Table in TM 9-4933-200-35.

TASK: Inspect declutching feed mechanism, 20mm M163 (45L10)

ELEMENTS:
. Time gun to declutching feeder.

TASK: Replace transmission, 5-ton, M813 (63H10)

ELEMENTS:
. Reverse transmission vent lines.
. Adjust clutch linkage and free travel.
. Put lubricant in transmission.
. Put too much lubricant in transmission.
. Adjust pressure plate release levers.
. Adjust pressure plate.

*Also identified as a difficult element.

DISCUSSION

The results of the task analysis review and modification for each task indicate that the procedures can be used to provide task performance information at a level of detail sufficient for test construction. All elements required for successful task performance were included in the revised task analysis.

The reader will recall that the second purpose of the review and modification procedures was to enable test developers to identify task elements whose successful performance predicts overall task performance. The SME selection of difficult elements for each task was to be verified by testing a group of soldiers who had been trained on the task and comparing their performance on each element with SME predictions of the most difficult element(s). For a variety of reasons, the verification did not proceed as planned. Essentially, each task took so long to perform, at least for soldiers at the entry-level of experience, that there was neither the time nor the equipment available to conduct the verification. For this reason, other ways were considered to verify a set of procedures that would enable test developers to identify predictive elements systematically.

CHAPTER 3

STUDY II: IDENTIFYING PREDICTIVE ELEMENTS DIRECTLY FROM SME JUDGMENTS

Test results from a world-wide Army Training Study (ARTS) appeared promising as a set of data for studying the validity of element selection procedures. Included in these data were six tasks from the 63H10 automotive mechanic and six tasks from the 63C10 tracked vehicle MOS. The plan was to have SME select directly elements to test rather than the more indirect approach of rating elements for difficulty and criticality. If SME agreement levels were satisfactory, the SME selections could be compared with available performance results on the large sample of soldiers. The tasks used in the ARTS are considerably shorter in terms of number of elements and time to perform than are the three original tasks. However, if the procedures could be verified on short tasks, they would work on long tasks, which may be viewed essentially as a collection of short tasks.

METHOD

This second procedure for task analysis review and modification focused exclusively on the second purpose (identifying predictive elements) for an SME review of task analysis. The first purpose of an SME review procedure (to provide task performance information at a level of detail sufficient to be useful for test construction) was met by the initial procedures (Appendix A). Therefore, project staff conducted the task analysis review for this purpose. In the course of this review, three tasks (63H, Tasks 2, 3, and 5) were modified. The study entailed the development and administration of a questionnaire to elicit SME judgments about priority task elements for testing. Performance on these elements was then to be rescored by task for soldiers tested in ARTS, and the "part-task" scores correlated with whole task performance. Low agreement among SME ratings, unfortunately, precluded the planned analysis. Questionnaire preparation and administration were as follows.

Task Element Selection Questionnaire

The selection questionnaire contained twelve questions. Four questions concerned selecting a specific number of task elements (from one to four) which, if the soldier performed successfully, would convince the SME that the soldier could perform the entire task successfully. The four questions were:

1. You want to know if a soldier can do this task. There is time for him to do only <u>one</u> of the elements for the task. Which <u>one</u> element would you want to see him do?

2. You want to know if a soldier can do this task. There is time for him to do only <u>two</u> of the elements for the task. Which <u>two</u> elements would you want to see him do?

3. You want to know if a soldier can do this task. There is time for him to do only <u>three</u> of the elements for the task. Which <u>three</u> elements would you want to see him do?

4. You want to know if a soldier can do this task. There is time for him to do only <u>four</u> of the elements for the task. Which <u>four</u> elements would you want to see him do?

Four questions asked SME to select elements to test given four time periods for testing. The four questions were:

5. You want to know if a soldier can do this task. You only have <u>five</u> minutes for the test. Which element or elements would you want to see him do?

6. You want to know if a soldier can do this task. You only have <u>ten</u> minutes for the test. Which element or elements would you want to see him do?

7. You want to know if a soldier can do this task. You only have <u>fifteen</u> minutes for the test. Which element or elements would you want to see him do?

8. You want to know if a soldier can do this task. You only have <u>twenty</u> minutes for the test. Which element or elements would you want to see him do?

Two questions were asked to determine SME opinion of the most difficult element. The two questions were:

9. Which element do you think is <u>most often performed wrong</u>?

10. Which element do you think is the <u>most difficult to do</u>?

Two questions were asked to determine the critical elements. The two questions were:

11. Sometimes doing a task involves elements that are very important in the sense that doing them wrong, or not doing them, can cause immediate and sometimes irreversible damage to the soldier or equipment (pressing the starter button on a tank for longer than 15 seconds). Which elements in this task can cause immediate damage to the soldier or equipment if done wrong (or not done)?

12. Sometimes doing a task involves elements that are very important in the sense that doing them wrong, or not doing them, can be potentially serious for the soldier or equipment but not detected while the task is being done (failing to tighten hub nuts on a 1/4-ton truck to the specified torque). Which elements in this task can cause damage to the soldier or equipment if done wrong (or not done) but might not be detected while the task is being done?

Questionnaire Administration

The questionnaire was administered to five NCO at Ft. Knox, Kentucky, and six at Aberdeen Proving Ground. Table 4 describes the SME by PMOS and duty position. The SME worked with one task at a time and answered all questions for the task before starting another task. The list of tasks for each MOS and the number of task elements in each are shown in Table 5. The task elements for each task reviewed by the SME are presented at Appendix C. It is important to note that the SME only responded to tasks on which they were familiar. Therefore, the number of SME responding to each task is not always the same. The questions were given orally by a member of the project staff; the SME, however, worked independently

RESULTS

The SME selection data were analyzed for inter-judge agreement. In order for the selection procedures to be systematic and useful for test developers, it is necessary that they produce consistent results. High agreement among SME would indicate that having one SME select elements would be as valid as collecting the same information from any other, or from many SME, with a considerable savings in time and effort. This is particularly a requirement for test developers who have access to only one or two SME.

Table 4

SME By PMOS and Duty Position

Location	PMOS	SME Number*	Duty Position
Ft. Knox, Kentucky	63H40	1	Maintenance Sergeant
	63H30	2	Material Section
	63H30	6	Supply Sergeant
	63B30	5	Maintenance Sergeant
	63H20	4	Track Vehicle Inspector
Aberdeen Proving Ground, Maryland	63H40	3	Task Analysis Committee
	63H30	11	Task Analysis Committee
	63H30	7	SQT Writer
	63H30	8	SQT Writer
	63H30	9	Instructor, Mobility Branch
	63H30	10	Instructor, Mobility Branch

*Randomly assigned for analysis purposes.

Table 5

63H and 63C Tasks

Task	Number of Task Elements
63H	
1. Adjust transmission linkage on M113A1.	8
2. Inspect M35A2 electrical system.	12
3. Adjust cam dwell on M151A1/A2 truck.	12
4. Adjust clutch cover assembly on M809 series truck.	7
5. Test and adjust alternator voltage output on M151A1/A2 truck.	6
6. Remove and replace front differential on M151A1/A2 truck.	10
63C	
1. Troubleshoot 25 ampere DC charging system.	8
2. Troubleshoot starting system circuit on M151A1/A2 truck.	11
3. Replace steering linkage on M151A1/A2 truck.	8
4. Troubleshoot brakes and controls on M151A1/A2 truck.	5
5. Troubleshoot CD850 transmission, M60A1.	12
6. Adjust shift control linkage, M60A1.	8

A data matrix was prepared for SME responses for each task. The data matrix for SME responses to 63H task #3 (Adjust cam dwell on M151A1/A2 truck) is displayed in Figure 1. The data matrixes for the remaining tasks are at Appendix D. Pairwise agreements among SME were then computed for questions 1-4. (For the convenience of the reader, the 12 questions are listed in Table 6.) On question 1, a pairwise agreement occurs whenever one SME selects the same element as another SME. If four SME select the same element, six pairwise agreements are counted. Thus, if all 11 SME respond to question 1 on a given task, 55 pairwise agreements are possible. On question 2, two types of agreement can occur: two SME might pick the same two elements (full agreement), or they might agree on only one of the two elements each selected (partial agreement). With 11 SME responding, there are again 55 possible pairwise agreements, but 110 possible partial agreements. On question 3, partial agreement is possible at two levels (agree on one out of three elements, agree on two out of three elements), and on question 4 there are three levels of partial agreement. Partial agreements reported in Table 7 are all of the "one-or-more-out-n" sort. The figures represent obtained agreement as a proportion of possible agreement; the denominator varies as a function of the number of SME responding and the number of elements selected. (Occasionally, an SME would select fewer than the number of elements asked for.)

Agreement among SME was disappointedly low on all questions. Full agreement on the first four questions (Table 7) ranged over tasks from a low of 0 to a high of 60%, with an average of approximately 13%. Of the 48 full agreement percentages (four questions for each of 12 tasks), 17 exceeded chance expectations.[1] Statistical significance is not the only criterion or, for that matter, even the most important criterion. Practical significance, too, must be considered. And the observed levels of agreement fall substantially below that viewed as acceptable for practical purposes.

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[1]Chance expectations were calculated using the cumulative binomial formula (Lindgren, B.W. Statistical Theory (Second Edition). Macmillan, 1968, p. 150). The formula gives the probability of any number of successes in a number of trials, given the probability of success on a single trial. Here, a success is defined as a pairwise agreement among raters, and the number of successes ranges from the number of agreements observed to the number of trials occurring. The number of trials is the number of pairs of raters. The probability of success (agreement) on a single trial (pair of raters) varies as a function of the number of elements in the task and the number of selections the rater is to make. On question 1, for 63H Task 3, for example, there are 12 elements, and the nine raters are each to choose one element for testing. The number of trials in this case is 36, the number of pairs of raters. The probability of agreement for a single pair of raters is 1/12. Using these figures in the binomial formula for 11 to 36 agreements, the probability of obtaining 11 or more agreements, simply by chance, is .01. This may be compared to the 6 or more agreements of 36 which would be expected 5% of the time.

Task Number 3 (63H)
Adjust Cam Dwell on M151A1/A2 Truck

Question	SME # 1	2*	3	4*	5	6	7	8	9	10	11
1. Test one element	1		12		7	7	12	12	2	12	12
2. Test two elements	1, 2		10,11		1, 2	1, 2	12,10	8,12	2,12	9,12	11,12
3. Test three elements	1, 2 3		10,11 12		7, 8 9	1, 2 3	12,10 9	8, 9 12	2, 7 12	9,12 10	10,11 12
4. Test four elements	1, 2 3, 4		9,10 11,12		9,10 11,12	1, 2 3, 4	12,10 9,11	8, 9 10,12	2, 7 11,12	9,10 6,12	9,10 11,12
5. Five minutes to test	1-6		10		12	1-6	8, 9	8, 9 12	1, 2 3	10,12	1-6
6. Ten minutes to test	1-9		7, 9 10,12		1-5	1-10	8, 9 10,11	8, 9 10,12	1-5	9,10 12	All
7. Fifteen minutes to test	All		7, 9 10,11		1,11	All	8,12	6,10 12	---	---	---
8. Twenty minutes to test	All		7, 9 10,12		All	All	All	---	1-8	6, 9 10,12	---
9. Performed wrong	12		10		1	1	7	5	4	11	7
10. Most difficult	12		12		7	7	7	5	12	12	12
11. Immediate consequences	9		7		8	8	7	5	7	11	7
12. Undetected consequences	6		12		12	12	12	5	---	10	12

*SME not familiar with this task.
NOTE: Numbers in the cells refer to Task Element Numbers (See Appendix C).

Figure 1. Data Matrix for SME Responses to 63H Task #3.

Table 6

Questions for SME to Select Predictive Elements

1. You want to know if a soldier can do this task. There is time for him to do only one of the elements for the task. Which one element would you want to see him do?

2. You want to know if a soldier can do this task. There is time for him to do only two of the elements for the task. Which two elements would you want to see him do?

3. You want to know if a soldier can do this task. There is time for him to do only three of the elements for the task. Which three elements would you want to see him do?

4. You want to know if a soldier can do this task. There is time for him to do only four of the elements for the task. Which four elements would you want to see him do?

5. You want to know if a soldier can do this task. You only have five minutes for the test. Which element or elements would you want to see him do?

6. You want to know if a soldier can do this task. You only have ten minutes for the test. Which element or elements would you want to see him do?

7. You want to know if a soldier can do this task. You only have fifteen minutes for the test. Which element or elements would you want to see him do?

8. You want to know if a soldier can do this task. You only have twenty minutes for the test. Which element or elements would you want to see him do?

9. Which element do you think is most often performed wrong?

10. Which element do you think is the most difficult to do?

11. Sometimes doing a task involves elements that are very important in the sense that doing them wrong, or not doing them, can cause immediate and sometimes irreversible damage to the soldier or equipment (pressing the starter button on a tank for longer than 15 seconds). Which elements in this task can cause immediate damage to the soldier or equipment if done wrong (or not done)?

12. Sometimes doing a task involves elements that are very important in the sense that doing them wrong, or not doing them, can be potentially serious for the soldier or equipment but not detected while the task is being done (failing to tighten hub nuts on a 1/4-ton truck to the specific torque). Which elements in this task can cause damage to the soldier or equipment if done wrong (or not done) but might not be detected while the task is being done?

Table 7

Pairwise Agreement Among SME
On Selection Questions 1-4

Task	Number of Elements	Number of SME	Full Agreement Question 1	2	3	4	Partial Agreement Question 2	3	4	
63H 1	8	5	0/10	1/10	1/10	0/6	5/20	12/30	19/36	
2	12	11	7/55	4/55†	2/55†	3/55†	45/110	82/165	114/220	
3	12	9	11/36†	3/36†	3/36†	8/36†	12/72	35/108	71/144	*
4	7	9	18/36†	4/36	3/36	1/28	28/72	66/108	71/112	
5	6	9	8/36	8/36†	7/36†	6/21†	36/72	68/108	109/129	
6	10	10	4/45	3/45	6/45†	3/36†	23/90	45/135	72/144	
		AVERAGE	20.7%	10.9%	12.4%	11.4%	32.8%	46.9%	58.6%	
63C 1	8	6	2/15	1/15	1/15	1/15	8/30	24/45	37/60	
2	11	5	1/10	0/10	0/10	0/6	5/20	6/30	8/36	
3	8	10	16/45†	4/45	4/45†	2/36	25/90	64/135	105/171	
4	5	11	11/55	3/45	5/55	14/55	39/100	96/165	149/2[illegible]0	
5	12	5	6/10†	1/10	0/10	0/10	7/20	11/30	14/40	
6	8	4	1/6	2/6†	0/6	1/6	4/12	5/18	13/24	
		AVERAGE	25.9%	10.9%	4.1%	9.1%	31.1%	40.6%	50.4%	

*See Figure 1 for raw data.

†Binomial probability < 5%.

Partial agreement results for questions 2-4 (Table 7) though numerically larger, are not much better with respect to chance expectations than were results for full agreement. Responses on questions 9-12 (Table 8) show similarly low SME agreement, the rates typically being below 25%.

Because the SME responses to questions 5-8 (elements to test under four different time constraints) varied so widely, pairwise agreements for these questions were not computed. However, in the interest of exploring the similarity of task dimensions being considered by raters in responding to these questions versus questions 1-4, responses to the two sets of questions were correlated. Elements on each task were rank-ordered according to their importance in SME selections. An element selected by an SME in response to question 1 was given a weight of 4, responses to question 2 were given a weight of 3, and so on. Responses to questions 5-8 were similarly weighted and rank-ordered. Correlations of the two orders (Table 9) ranged widely--from .10 to .92 depending on the particular task involved. No evident characteristics, such as type of task or number of elements, however, were systematically associated with these differences in correlation.

DISCUSSION

Inter-judge agreement levels were so low that no attempt was made at this point to verify the selection procedures by comparing the ARTS performance data with the SME selected elements. Any discussion of the causes of such low agreement is, of course, speculative in nature but instructive in terms of modifying the selection instruments and procedures.

One would anticipate that question 9 ("performed wrong") and question 10 ("most difficult") would have the highest agreement not only among SME but also within an SME. Neither of these expectations was met at an agreement level satisfactory for any systematic decisions. Agreement among SME on question 9 averaged 22.1% on the 63H tasks and 23.7% on the 63C tasks; agreement on question 10 averaged 39.3% on the 63H tasks and 27.6% on the 63C tasks. The within SME agreement was 40% across all the tasks; that is, only 40% of the time did an SME select the same elements for both questions. The low agreement among SME is probably a result of the experience factor; whatever element is a problem for the SME when he performs the task is the element he selects. The low agreement within an SME is most likely a result of different interpretations of the two questions.

Questions 1 through 4 seem reasonable from an element selection view point but agreement was much too low. Agreement increases with increases in the number of elements one is permitted to select;

Table 8

Pairwise Agreement Among SME
On Selection Questions 9-12

Task	Number of Elements	Question 9	Question 10	Question 11	Question 12
63H 1	8	4/10	3/10	3/19	2/10
2	12	8/55	28/55	22/87	14/127
3	12	2/36	18/36	9/36	10/28 *
4	7	10/52	15/35	4/21	12/44
5	6	16/36	16/36	7/28	4/35
6	10	4/45	8/45	15/54	19/85
	AVERAGE	22.1%	39.3%	23.0%	21.3%
63C 1	8	2/20	3/15	5/26	4/20
2	11	4/32	3/33	5/24	3/14
3	8	19/86	8/53	10/53	26/98
4	5	36/45	11/36	4/28	23/94
5	12	2/14	6/10	1/9	1/6
6	8	3/9	4/13	0/3	0/6
	AVERAGE	23.7%	27.6%	14.0%	18.2%

*See Figure 1 for raw data.

Table 9

Correlation in Rank Order of Elements
As Assigned by SME on Selection Questions 1-4 and Questions 5-8

Task	Number of Elements	Rho	Significance
63H 1	8	.5952	NS
2	12	.4021	NS
3	12	.3077	NS *
4	7	.8571	$p < .05$
5	6	.8286	$p < .10$
6	10	.2242	NS
63C 1	8	.7738	$p < .05$
2	11	.4955	NS
3	8	.7619	$p < .05$
4	5	.1000	NS
5	12	.4248	NS
6	8	.9226	$p < .05$

*See Figure 1 for raw data.

however, that is to be expected since the opportunity for agreement is increased. The low agreement among SME for the first question, averaging 20.7% for the 63H tasks and 25.9% for the 63C tasks, was discouraging since this question seemed the more simple and unambiguous of those asked.

Little more can be said regarding SME agreement levels. The selection instrument could be modified by deleting the questions concerning time limits (questions 5 through 8) as these seemed the most ambiguous to SME; questions 3 and 4, regarding additional elements to test, could also be deleted since SME felt that two elements were sufficient. But these deletions would still leave questions which, without more experienced SME or perhaps SME better trained in making such analytic judgments, cannot be answered reliably.

CHAPTER 4

STUDY III: IDENTIFYING PREDICTIVE ELEMENTS EMPIRICALLY

Since the selection of predictive elements by SME proved unreliable and therefore unusable, another approach was tried. The performance data for the ARTS tasks were examined to determine empirically the most likely testing point(s) within each task. If key testing points (i.e., elements highly predictive of total task performance) could be identified in this way, it might then be possible to develop from the empirical data procedures for test developers that would enable them to select these same testing points without benefit of test results. For example, there may be a type of element among all adjustment tasks (63H tasks 1, 3, and 4; 63C task 6) that is typically performed incorrectly by nonperformers, and typically performed correctly by performers; that type of element could then be identified as a key testing point in test development procedures for that type of task.

METHOD

The objective was to identify the most predictive task element(s) and the most difficult task element(s) for each of the twelve tasks, examine these elements for any characteristics which tie them together, and then develop rules for selecting elements with these same characteristics. First, any soldier who did not complete the task was eliminated from the data base for that task. Task completion is not to be confused with successful task performance; soldiers were permitted, in fact, encouraged, to continue the task if they made an error on one or more task elements. The number of soldiers completing each 63H task and each 63C task and used in the analyses is presented in Tables 10 and 11, respectively.

When the tasks were administered for record (during the ARTS), scorers were permitted to "prompt" soldiers who were having difficulty performing a task element; if he then performed the element successfully, the soldier was given a GO for the element. The scorer, however, indicated on the scoresheet the number of prompts, if any, given for the element. Any task element that had a GO with a prompt was converted to a NO GO. This was done for two reasons. First, if a soldier needs a prompt, he doesn't know how to perform the task element and second, the number of NO GO was increased to give a more acceptable variance in scores.

Once the data were "clean"--that is, soldiers eliminated who did not complete the task--and a GO-with-a-prompt for any task element converted to a NO GO, two statistical analyses were performed: Forward Stepwise Multiple Regression, and Guttman Scalogram Analysis.

Table 10

63H Tasks

Task	Number of Soldiers[a]
1. Adjust transmission linkage on M113A1.	151
2. Inspect M35A2 electrical system.	108
3. Adjust cam dwell on M151A1/A2 truck.	90
4. Adjust clutch cover assembly on M809 series truck.	79
5. Test and adjust alternator voltage output on M151A1/A2 truck.	105
6. Remove and replace front differential on M151A1/A2 truck.	132

[a]This is the number of soldiers who completed the task out of the 190 who began the task.

Table 11

63C Tasks

Task	Number of Soldiers[a]
1. Troubleshoot 25 ampere DC charging system.	94
2. Troubleshoot starting system circuit on M151A1/A2 truck.	101
3. Replace steering linkage on M151A1/A2 truck.	96
4. Troubleshoot brakes and controls on M151A1/A2 truck.	135
5. Troubleshoot CD850 transmission, M60A1.	131
6. Adjust shift control linkage, M60A1.	128

[a]This is the number of soldiers who completed the task out of the 137 who began the task.

Forward Stepwise Multiple Regression

This is a procedure through which one can analyze the relationship between a dependent or criterion variable and a set of independent or predictor variables.[1] For the ARTS data, total test score is the criterion and each task element is a potential predictor. In predicting values of the criterion or dependent variable from the set of predictor or independent variables, the regression analysis first selects the independent variable which has the highest correlation with the dependent variable. This correlation, when squared, expresses the variance in the dependent variable which is accounted for by, or predictable from, the independent variable. That independent variable's influence is then partialled out; the next independent variable to enter the regression is the one which accounts for the greatest proportion of variance in the dependent variable which is not yet accounted for by the leading independent variable. The process continues, at each step producing a (multiple) correlation which, squared, indicates the variance accounted for by all independent variables entered up to that step. The standard error of estimate computed at each step indicates the average error in prediction which would occur if the dependent variable was predicted from the independent variables entered up to that step.

Guttman Scalogram Analysis

This procedure analyzes the underlying operating characteristics of items to determine if their interrelationships meet several special properties which define a Guttman scale. First, the items must be unidimensional; that is, they must all measure a single underlying object or ability. Second, the items must be cumulative; that is, they can be ordered by degree of difficulty as indicated by respondents who pass a difficult item always passing less difficult items, and vice versa.[2] The elements are thus arranged in order of difficulty, and certain statistical tests applied to determine how well the data actually conform to these expected tendencies. These tests measure whether elements are unidimensional and cumulative; that is, whether they tap the same underlying abilities and are more or less hierarchial in their requirement for demonstration of the underlying ability. The tests are: (a) Coefficient of Reproducibility (CR), which is a measure of the extent to which a person's total task score predicts his task element pass pattern; (b) Minimum Marginal Reproducibility (MMR), which gives the minimum CR that could have occurred for the task given the proportion of people passing and failing each element:

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[1]Nie, N.H., Hull, C.H., Jenkins, J.G., Steinbrenner, K., and Bent, D.H. SPSS: Statistical Package for the Social Sciences (Second Edition). McGraw-Hill, 1975.

[2]Ibid.

(c) Percent Improvement (PI), or the difference between CR and MMR; and (d) Coefficient of Scalability (CS), which provides an indication of the extent to which the scale is truly unidimensional and cumulative.

RESULTS

The ARTS performance test results were examined and two hypotheses tested by means of the multiple regression and scalogram analyses. The two hypotheses were:

1. The regression analysis would identify a subset of elements of each task which would predict task performance; that is, would account for more of the variance in total task scores.

2. The Guttman scale analysis would provide a reliable ordering of the elements of each task; that is, the elements would prove to be unidimensional and cumulative.

Regression Analysis

In the multiple regression analysis the ARTS tasks were analyzed individually. The independent variables were outcomes on each task element (pass or fail), and the dependent variable was total task score, the number of elements passed. Thus, unlike most regression problems, it is always possible to predict the dependent variable without error, simply by adding the values of all the independent variables. The purpose of the multiple regression analysis was to determine the subset of independent variables (elements) which could together account for most of the variance in the dependent variable (task performance), and predict the dependent variable within acceptable error limits. The means and standard deviations for the tasks are presented in Appendix E; the regression summary scores for the tasks are in Appendix F.

As may be seen in Table 12, at least half of the task elements, in all but two tasks, had to be entered into the regression in order to account for 90% of the variance in total score. In five of the tasks, more than half of the elements each accounted for up to 5% of the variance.

In these data, it is apparent that any attempts to determine task performance from knowledge of performance on only a subset of elements will result either in considerable prediction error, or in miniscule savings in testing time. But a closer examination of the data reveals possible mitigating circumstances which may explain why so many elements had to enter the regressions for relatively error-free prediction.

Table 12

Summary of Multiple Regression Analysis Where Dependent Variable Is Task Score (Elements Passed) And Independent Variables Are Task Elements

Task		Number of Elements: In Task	Required To Account For 90% of Variance	Contributing At Least 5% To Variance Accounted For
63H	1	8	4	3
	2	7[a]	6	7
	3	13[a]	5	3
	4	7	4	4
	5	7[a]	5	5
	6	10	5	4
63C	1	8	6	7
	2	11	7	4
	3	8	3	3
	4	5	4	5
	5	12	8	5
	6	8	5	4

[a]The number of task elements on which examinees were scored is different from the number reviewed by SME because of task analysis modification (discussed earlier).

Although the data were initially adjusted so that prompted elements were considered as failures to perform, the variance within tasks was still small, and the distribution of scores was markedly skewed (see Table 13). The ideal data for producing a promising regression would have total scores distributed somewhat normally, with an average of around half the elements passed and frequency of scores trailing off toward the extremes of perfect performance or complete failure. Element difficulties would also spread normally, between .8 and .2 (ideally, all would be close to .5). Element correlations would be somewhat clustered; that is, some elements would have high intercorrelations with each other, and low correlations with other groups of elements, each of which would also correlate highly among themselves. There would be few, if any, negative correlations, and no high negative correlations. Correlations between elements and total score would all be moderate, with at least one element in each group of highly correlated elements having a relatively high correlation with total score.

In the ARTS data, these conditions did not obtain. Because of the way in which performance data are necessarily collected and the sequential nature of task elements, a failure on a task element often means that the examinee cannot even attempt subsequent elements. Regression analysis of the type performed requires complete data on all subjects; data for those who did not complete the task could not be included in the analysis. The result is that element difficulties (percent failing) are spuriously low. Even though examinees tended to fail seemingly random elements (an examinee with a high score did not necessarily fail only the more difficult elements, nor did an examinee with a low score pass only the easier elements), the large numbers of examinees passing each element produced many moderate correlations among elements and no clear clusters of elements. Many also tended to be highly correlated with total scores. Together, this meant that the first element in the regression might account for a sizable chunk of the available variance, but subsequent elements were able to contribute little to the prediction beyond what was already known.

If the regression were to be done with a simple GO/NO GO on task performance as the dependent variable, the order of entry of the task elements into the regression would change. The elements would then enter in order of difficulty. This has intuitive appeal: the more difficult elements, if performed correctly, should indicate something about ability to perform the less difficult elements, and, by extension, about ability to perform all elements correctly. Although the predictive order of the elements would be reasonable, the variance accounted for would be small, and the prediction fraught with error.

Table 13

Task Performance Characteristics

Task	Number of Elements	Mean Score	Standard Deviation	Average Element Difficulty[a]	Percent of Subjects With Perfect Performance	Average Correlation Among Elements	Average Correlation With Total
63H 1	8	7.119	1.194	.110	48.3	.202	.530
2	7	5.093	1.550	.272	23.1	.133	.505
3	13	10.733	2.979	.174	26.7	.340	.625
4	7	5.924	1.228	.154	40.5	.183	.526
5	7	5.067	1.396	.276	15.2	.170	.517
6	10	9.833	.582	.017	88.6	.113	.474
63C 1	8	5.553	1.349	.306	3.2	.048	.401
2	11	8.782	1.869	.202	14.8	.117	.440
3	8	7.667	1.043	.042	83.3	.429	.699
4	5	3.563	1.232	.287	26.7	.137	.555
5	12	10.030	1.835	.164	19.8	.130	.445
6	8	6.453	1.640	.193	32.8	.199	.540

[a]Average element difficulty is computed as the proportion of examinees failing each element, averaged across elements in the task.

Guttman Scalogram Analysis

Of the 12 tasks examined, none formed a scale (Table 14). Though three tasks had CR values greater than .9, the criterion for a valid scale, none had a PI index that exceeded 8%, indicating that examinees' total scores reveal little or nothing about which items they passed or failed. In other words, a low test score does not necessarily mean that the examinee failed all of the more difficult items nor passed only the easiest items; nor does a high score indicate that the examinee failed only the most difficult items. Any high CR in this case is due more to inherent cumulative interrelationships of the elements than to performance patterns. The low values of CS, which should be well above .6 if the scale is truly unidimensional and cumulative, indicate that the tests of these tasks are probably not unidimensional, and certainly not cumulative.

To determine whether the tasks, in fact, are not unidimensional, internal consistency estimates were computed for each task using Kuder-Richardson Formula 20.[1] As shown in Table 14, only two tasks had what might be considered high internal consistency (r_{tt} = .80). The rest were low to moderate, indicating that there is no common set of abilities uniformly required by all the elements. More likely, all elements in a task are linked by virtue of having been learned at the same time, but may have been learned to varying degrees of competency. In addition, the elements probably do require different skills and abilities since maintenance tasks tend to be heterogeneous, and one would expect low consistency. If it were possible to separate knowledge of task procedures (knowing what to do, where, and when) from ability to perform those procedures (the basic skills or abilities), the underlying skills might appear more str ngly. Each task would be more heterogeneous as a whole, but would be composed of subsets of homogeneous elements.

Empirical Versus SME Selections

Despite the low reliability of SME selections in the previous study, and at the risk of compounding measurement error, it was decided to check SME judgments against results of the empirical analysis. Since agreement among SME was so low, further analyses of the SME selections were confined to comparisons of the various methods of selection to see if any were more likely to elicit responses which agreed with the results of the ARTS data analyses. Questions 1-4 were treated as four separate methods of task element selection. For question 1, an agreement was counted whenever an SME selected the element which was the lead predictor in the regression analysis. For question 2, a full agreement occurred when

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[1]Guilford, J.P. Psychometric Methods (Second Edition). McGraw-Hill, 1954, p. 380.

Table 14

Guttman Scale Analysis and Internal Consistency

Test	Guttman Scale Test Statistics[a] CR	MMR	FI	CS	Internal Consistency
63H 1	.926	.890	3.6%	.323	.592
2	.783	.728	5.6%	.204	.524
3	.837	.822	1.5%	.083	.843
4	.879	.846	5.2%	.341	.539
5	.815	.736	7.9%	.299	.482
6	.980	.983	- .3%	-.182	.568
63C 1	.774	.718	5.6%	.198	.217
2	.811	.798	1.3%	.062	.579
3	.974	.958	1.6%	.375	.811
4	.787	.713	7.4%	.258	.442
5	.838	.836	.2%	.015	.601
6	.846	.807	3.9%	.202	.652

[a]See text.

the SME selected the two lead elements, and a partial agreement when one of the two lead elements was selected. With questions 3 and 4, there are two and three levels of partial agreement, respectively. The agreements were added across tasks,[1] for full and partial agreements on each question, for each SME. The sums were then converted to proportions (agreements divided by number of selections) and averaged across SME. Similarly, the expected agreements were calculated for all full and partial agreements for each SME and averaged across SME. The results are shown in Table 15, with expected agreements in parentheses next to each observed agreement. A goodness-of-fit test[2] indicated that questions 2 and 3 elicited more full agreements than would be expected by chance. Such results, however, are not strong enough to decide on a preferred method of element selection.

Question 9, concerning the element most often performed wrong, was compared with the obtained difficulty levels of elements. Across tasks, SME selected the most difficult element in 16.1% of their selections. When an agreement was counted if they selected either of the two most difficult items, their agreement rate was 35.5%; when the standard was further relaxed to any of the three most difficult items in a task, their rate was still only 45.3%. None of these rates is acceptable in terms of a systematic selection method.

DISCUSSION

A statistical approach to task element analysis of the sort attempted here is clearly appropriate and feasible. In this particular case, however, scoring shortcomings and variance restrictions in the data tended to limit opportunities for meaningful results. Too many task elements tended to emerge in achieving predictability of total task score. Moreover, the elements that were identified as most-predictive seemed to have little in common, whether viewed within a task, a task category, or over all tasks.

Inconclusive though these results were, it is difficult to relinquish the belief that "most-predictive" elements, if reliably established,[3] indeed have something in common. It seems only reasonable that within a set of highly similar tasks whatever underlies the predictiveness of one most-predictive element also underlies the predictivensss of other most-predictive ones. The problem is to capture that underlying construct. And to do this one needs to know not only

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[1]Data for the three tasks for which task analyses were modified (63H, tasks 2, 3, and 5) were not included in this analysis.

[2]Lindgren, B.W. <u>Statistical Theory</u> (Second Edition), p. 325.

[3]It should be noted that in studies such as this the reliability of element predictiveness should be verified through cross-validation on a second sample of examinees.

Table 15

Observed and Expected Agreements
Between SME Selections and Empirical Selections

Agreement	Question 1	2	3	4
No Agreement	76.5 (86.4)*	45.0 (50.4)	16.8 (16.9)	3.5 (3.1)
One Element	23.5 (13.6)	45.5 (44.9)	35.6 (47.5)	20.0 (21.0)
Two Elements	-	9.3 (4.7)**	41.5 (32.2)	26.5 (36.6)
Three Elements	-	-	5.5 (3.4)*	43.6 (33.7)
Four Elements	-	-	-	6.4 (5.5)
At Least One Element	-	32.2 (27.2)	45.3 (40.6)	55.2 (54.4)

*$p < .10$

**$p < .05$

what task elements an examinee misperformed but exactly why or precisely what aspect of the element was failed. The importance of such detailed diagnostic data is illustrated in the following example. Consider two maintenance tasks each with an element that requires torqueing a bolt, and each with an element that requires testing the vacuum in a line. Further, suppose that the predominant correlate of failure on Task A was failure on the bolt-torqueing element, whereas on Task B it was the vacuum test. One would be tempted to attribute such results to a lack of internal consistency over the tasks. That is, why would poor performers fail bolt-torqueing (or vacuum testing) on one task but pass it on another? If there is an underlying common skill, what is it? Further probing might reveal that these "most-predictive" elements both involved system components that were inaccessible, that the modal reason for failure had nothing to do with how to use a torque wrench or vacuum gauge, but with how to locate equipment points that are inaccessible or difficult to identify from the job aid. Thus, an underlying skill, different in kind from that expected, may be found which behaviorally ties together statistically reliable but ostensibly unrelated pass-fail patterns over tasks. The ARTS data available in this study unfortunately did not offer the detailed diagnostic information needed to carry out this sort of penetrating analysis.

It should be noted, however, that even if a thorough analysis of diagnostic data was done and the underlying source(s) of commonality located, the result may be of little use in test development. Most-predictive elements may be mediated by factors that are difficult, if not impossible, to generalize to new tasks in the course of fore-casting their relevance for test development. Most-predictive elements may be united by such underlying factors as elements poorly covered in training, or elements that cannot be observed, or those poorly described in the job aid.

CHAPTER 5

GENERAL DISCUSSION

If time- and resource-consuming tasks are to be tested feasibly, a way of testing just the more relevant task behaviors must be found. Any such method must entail test developers forecasting reliably those task elements most predictive of whole task performance. The forecasting, moreover, cannot proceed task by task from an empirical analysis of element task correlations--that simply is not practical. Needed are guidelines which, by type of task and configuration of task elements, enable the developer to choose reliably the most predictive subset of elements to test.

Results of the work reported here indicate that task experts are not able to select relevant elements for testing, at least for the sample of maintenance tasks used. Since experts were not able to agree in their selections of relevant behaviors to sample for testing, it is evident that subjective approaches to identifying predictive elements of tasks for testing purposes are not fruitful.

More must be learned, first, about the nature of causes underlying the internal consistency (or inconsistency) of task performance and. second, about how these causes change systematically from one class of tasks to another. Only then can the test developer be given useful guidance for sampling task performance.

Empirical analyses in the general form of Study III reported here should be carried out. But they must be more carefully designed. At a minimum, they should meet three requirements:

1. Enough examinees, with a range of ability on the tasks, must be tested to insure variance in performance scores.

2. The performance data must include not only the pass/fail scores on elements, but also the reason why an examinee fails an element.

3. The tasks tested must represent all skills required for the job.

The first requirement, that there be many examinees and that the data have a high variance, is important in order to draw valid and reliable conclusions concerning predictive elements. If there are many examinees who all do very well or very poorly on the test of a task, no inferences are possible concerning which elements are predictive of ability to perform. If performance varies widely but only a few examinees are tested, any conclusions would be suspect by reason of statistical error. The most cost-effective method of testing many examinees is to focus on short tasks, with low to moderate time and equipment requirements. In order to insure control over the variance in performance, a more ambitious approach would involve training examinees to varying levels of competency.[1]

The second requirement, that performance data be more diagnostically precise, makes possible a more definitive statement of reasons for performance deficiency. Some elements, although stated concisely, will involve more than one behavior even though the observable, scorable behavior is unitary. For example, the element, "Connect transmission vent line," is easily observed and scored. However, if the examinee receives a fail for the element, we do not know whether he simply didn't do it, or didn't know where or how to connect the vent line, or didn't know what the transmission vent line was, or didn't connect it properly. Two elements, seemingly unrelated in behavioral requirements, may cluster as predictors because of common underlying reasons for failure. Each element must be broken down into underlying skill requirements.

The third requirement, that the tasks selected for testing represent all skills required for the job, insures that the elements which are determined to be predictive of performance are in fact the most predictive. With all skills represented, it would be possible to determine clusters of elements which are predictive and generalizable across tasks, rather than simply within tasks. The skills to be represented should be non-task-specific, such as those defined by Powers[2] (Figure 2).

Data which meet these three requirements may then be used to determine which elements, or specifically, which skill requirements are predictive of job proficiency. It may be that a different skill taxonomy is required. It may even be that no useful skill taxonomy exists for maintenance tasks, or that elements which fall neatly into skill categories are still independent in terms of predicting proficiency. But if useful skill categories are defined, and if task elements may be reliably assigned to categories on a rational basis (as opposed to empirical assignment), then an efficient method of testing may be developed.

For example, consider the display shown in Figure 2. If the columns represent verified generalizable skills, and the x within a column indicates that one or more elements of a task require that skill, two approaches would be warranted. First, the test developer might administer a collection of skill tests, not necessarily part

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[1]Osborn, W.C. and Ford, J.P. Research on Methods of Synthetic Performance Testing. HumRRO Final Report FR-CD(L)-76-1, April 1976.

[2]Powers, T.E. Selecting Presentation Modes According to Personnel Characteristics and the Nature of Job Tasks. Part 1: Job Tasks. University of Maryland Baltimore County, January 1977.

SKILL TASK CATEGORIES[1]

TASKS	1 Parts Relation	2 Parts [illegible]	3 [illegible]	4 Tool Names, Basic	5 Tool Names, Special	6 Test Equipment, Basic	7 Test Equipment, Special	8 Use Tools, Basic	9 Use Tools, Special	10 Use Test Equipment, Basic	11 Use Test Equipment, Special	12 Visual Aids	13 Assy/Disassy Procedures	14 Maintenance Procedures, Basic	15 Maintenance Procedures, Special	16 Calibrations
Adjust transmission linkage, M113A1	x	x	x					x						x		
Adjust cam dwell, 1/4 ton	x		x		x		x		x		x				x	x
Adjust clutch cover assembly, M809								x					x			x
Adjust alternator voltage output, 1/4 ton	x		x		x		x		x		x				x	x
Adjust shift control linkage, M60A1	x	x	x					x					x	x		

[1]Powers, T.E. Selecting Presentation Modes According to Personnel Characteristics and the Nature of Job Tasks. Part I: Job Tasks. University of Maryland Baltimore County, January 1977.

Figure 2. Skill Tasks by Tasks Descriptor Patterns (Example).

of any task, so that each skill is demonstrated at the end of the course. Another approach might be to select tasks for testing in such a way that each skill is demonstrated. The skill test approach has the advantage of selecting the "most generalizable" element for testing (if such a thing is found to exist). In that way, the approach reduces sampling error. The comprehensive task approach has the advantage of yielding direct information about ability to perform some of the domain. Both approaches offer the opportunity for inferring proficiency on untested behaviors.

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APPENDIXES

APPENDIX A

TASK ANALYSIS REVIEW AND MODIFICATION PROCEDURE

TASK ANALYSIS REVIEW AND MODIFICATION PROCEDURE

Item 1. Some maintenance activities take a long time to complete. For example, it takes six to eight hours to replace the cannon tube and four to six hours to replace the counter recoil buffer on the M109A1 SP Howitzer. There are, however, some natural breaks or separations in most of the activities. For purposes of the task analysis review, we will refer to these breaks as subtasks. Replace the counter recoil buffer, then, breaks into six subtasks:

Subtask 1 - Remove counter recoil buffer.

Subtask 2 - Push cannon tube out of battery.

Subtask 3 - Install counter recoil buffer.

Subtask 4 - Pull cannon tube into battery.

Subtask 5 - Fill and bleed replenisher system.

Subtask 6 - Fill out DA Forms 2404 and 2407.

The first thing you must do during the task analysis review is to identify the natural breaks in the activity and designate those breaks as subtasks. Each of the subtasks must define an action that has a measurable outcome. Go through the Job Data Worksheet (JDW) for the activity and designate the subtasks.

Subtask 1 - ______________________________

Subtask 2 - ______________________________

Subtask 3 - ______________________________

Subtask 4 - ______________________________

Subtask 5 - ______________________________

Subtask 6 - ______________________________

For the remainder of the review procedure, work with your Subtask 1; then, repeat the procedure for the remaining subtasks you identified for this activity.

Item 2. Consider the following conditions under which the subtask might be performed:

- Different equipment (M109 SP Howitzer/M110 SP Howitzer)
- Number of people performing the subtask (2 during day/ 3 at night)
- Equipment condition (new 5-ton, M818/old 5-ton, M818)

Are there different conditions under which this subtask might be performed?

Yes ______

No ______

If Yes, specify: ____

____

____

____

Is the subtask performed the same under those different conditions?

Yes ______

No ______

If No, please specify which conditions and how the subtask would be done different. For example, the task, "Drive a 1/4 ton truck," is an obvious case of varying conditions affecting task performance. Drive how and where? Cross country? In snow? On dry road? At night? With blackout? Any of these conditions will change the way the task is performed.

Condition	Difference in Subtask

Item 3. Does the JDW give a complete listing of all elements (decisions or actions) necessary for identification of successful subtask performance?

Yes ______

No ______

If No, what elements should be:

Added to permit identification of correct performance?

____

____

____

____

Deleted because not needed to identify correct performance?

____

____

____

____

Revised to permit identification of correct performance?

____

____

____

____

Item 4. You have seen this subtask performed many times. Of the times you have seen soldiers fail to perform it successfully, why have they failed? Where do they usually go wrong? For example, is it because they select the wrong tool, or use incorrect lubricants? Please consider the original list of task elements, plus any revisions you may have made, and identify the element that is the most frequent cause of failure and describe what the soldier does wrong.

Element	What Is It That They Do Wrong?
________	________
	________
	________

Are there other subtask elements that stand out in your memory as frequent causes of failure? If so, please list them.

Element	What Is It That They Do Wrong?
________	________
	________
	________

Item 5. Sometimes performance of a subtask involves elements that are very important in the sense that failure to perform those elements can lead to serious consequences, serious injury to the soldier, or serious damage to equipment. Sometimes this is immediate and may have irreversible consequences (pressing the starter button on a tank for longer than 15 seconds); other times it is potentially serious but undetected until damage occurs (failing to tighten hub nuts on a 1/4 ton truck to the specified torque). Are such elements part of the subtask?

Yes _____

No _____

If Yes, identify them, describe what the soldier does wrong, and indicate what the consequences are.

Element	What Is It That They Do Wrong?	What Are the Consequences of Incorrect Performance?
________	________	________
________	________	________
________	________	________

Item 6. Are there groups of elements where several sequences of performing are possible, but only one or some of those sequences are essential to correct performance? [Do not include elements which are sequential because of equipment design.]

Yes _____

No _____

If Yes, identify the groups of elements and essential sequence(s):

Element Group	Essential Sequence

If they're done out of sequence, can they be corrected at a later point without serious consequences?

Yes _____

No _____

If No, which ones can not be corrected?

Item 7. Is there a necessary time standard for any element?

Yes _____

No _____

If Yes, what element(s), and what is the time?

Element	Time

What happens if he doesn't do it within that time? For example, if a soldier depresses the starter button on a tank for longer than 15 seconds, the starter will burn out.

Element	What Happens

Now, return to Item 2, and repeat the review procedure for the next subtask.

APPENDIX B

REVISED TASK ANALYSIS FOR
"REPLACE TRANSMISSION, 5-TON, M813"

A. Disconnect powertake-off shaft and PTO linkage.

1. Place drain pan under vehicle at the transmission drain plug.
2. Remove transmission drain plug.
3. Loosen set screw on collar at splined end of the propeller shaft.
4. Move collar away from the yoke.
5. Loosen set screw on front universal joint yoke at the power take-off.
6. Slide yoke from power take-off shaft.
7. Remove cotter pin from shear pin at winch input shaft.
8. Remove shear pin at winch input shaft.
9. Slide yoke from winch input shaft.
10. Remove propeller shaft from vehicle.
11. Remove drain pan.

    . Transmission lubricant must drain for at least 15 minutes.

12. Install transmission drain plug.

    . Torque drain plug to 60-70 ft/lb.

B. Remove transmission.

1. Remove 16 bolts and nuts securing transfer to transmission propeller shaft.

2. Remove transfer to transmission propeller shaft.

3. Remove 20 screws and washers securing front tunnel and toeboard assembly to the cab floor.

4. Remove front tunnel and toeboard assembly.

5. Remove two capscrews and nuts securing two shift lever grommet clamps.

6. Remove shift lever grommet from shift lever housing cover.

7. Remove capscrew securing gear shifter lever to shift lever housing cover.

8. Disconnect main air supply hose, air cylinder to twin poppet valve tube, and twin poppet valve to transfer case tube from twin poppet valve assembly.

   . Each hose and tube must be labeled.

   . Each hose must be marked with a straight line at the point of hookup.

10. Disconnect transmission vent line.

11. Remove clevis pin securing clutch actuating lever connecting link rod assembly to clutch release lower actuating lever.

**12. Loosen top two capscrews securing clutch housing to flywheel housing.

   . Two capscrews must not be removed.

**13. Remove ten remaining capscrews and lockwashers.

**14. Place chain around transmission.

**15. Position heavy lifting device over transmission.

**16. Attach chain to heavy lifting device.

**17. Operate heavy lifting device until weight of transmission is observed.

**18. Remove two capscrews and lockwashers securing clutch housing to flywheel housing.

19. Slide transmission rearward to clear input shaft gear splines from clutch disc hub splines.

20. Lower transmission to the floor.

C. Remove clutch assembly.

1. Install clutch alinement tool or a transmission main drive gear into hub of friction plate assembly.

   . Pressure plate assembly must be marked in relation to engine flywheel.

**2. Install three 3/8-16UNC x 2 1/4 inches capscrews and 3/8 x 1 1/4 inch flat washers in the clutch assembly.

**3. Remove 12 capscrews and lockwashers securing cover assembly to engine flywheel.

   . Capscrews must be turned one or two turns in succession to avoid distortion of cover assembly.

4. Remove alinement tool (transmission main drive gear).

   . Clutch assembly must be secured.

5. Remove clutch assembly from engine flywheel.

D. Test and adjust clutch assembly and inspect pressure plate for warpage.

1. Check pressure plate for warpage.

. Place straight edge across pressure plate. Is there any space between straight edge and pressure plate?
Yes _____ No _____

- If Yes, do the following:

. Note deficiency on DA Form 2404.

. Turn pressure plate into supervisor.

- If No, continue with element 2.

*2. Adjust pressure plate cover assembly.

. Three shipping capscres are adjusted one-by-one until the pressure plate is exactly 1 9/32 inches from the inner surface of the pressure plate cover.

- Measurement is made directly below shipping capscrews.

- Slide T-rule is used to measure distance.

*3. Adjust release levers.

. Lay clutch pressure plate assembly face down on level surface.

. Loosen lock nuts of the release levers.

. Turn the adjusting nuts one-by-one until the top of the release levers are exactly 2 5/32 inches from the level surface.

- Slide T-rule is used to measure distance.

. Tighten lock nuts.

E. Install clutch assembly.

1. Install two alinement pins in holes where cover assembly is secured to engine flywheel.

2. Position engine flywheel, friction plate, and cover assembly in flywheel housing.

. Place cover assembly over two alinement pins.

. Do not get grease on any parts of clutch.

*3. Aline engine flywheel and friction plate.

. Engine flywheel and friction plate must be alined using a clutch alinement tool or a transmission main drive gear.

4. Install ten capscrews and lockwashers.

5. Remove two alinement pins.

6. Install two capscrews and lockwashers.

7. Tighten each capscrew alternately.

. Capscrews must be tightened alternately until clutch cover assembly is seated evenly to engine flywheel.

8. Torque capscrews to 28-32 ft/lb, evenly and alternately.

9. Remove clutch alinement tool (transmission main drive gear).

**/*10. Remove three 3/8-16 UNC x 2 1/4 inches capscrews and 3/8 x 1 1/4 inches flat washers.

F. Install transmission.

1. Install two alinement pins in top of flywheel housing.

2. Lift transmission.

3. Slide transmission input shaft up to clutch disc hub.

*4. Aline splines of input shaft to clutch disc hub.

. Did splines aline? Yes _____ No_____

- If No, do the following:

. Insert shifter lever in shifter housing cover.
. Place transmission in fourth or fifth gear.
. Turn output shaft slightly to aline splines.
. Continue with element 5.

- If Yes, continue with element 5.

5. Slide transmission forward over two alinement pins in top of flywheel housing.

6. Install ten capscrews and lockwashers.

7. Remove two alinement pins.

8. Install two capscrews and lockwashers.

9. Torque capscrews to 105-120 ft/lb.

10. Install transfer to transmission propeller shaft.

. Slip yoke must be toward the source of power.

. Heads of bolts must be on outside of transfer to transmission propeller shaft.

11. Connect transmission vent line.

12. Put gear shifter lever and retainer in place.

13. Install capscrew which secures gear shifter lever to shift lever housing cover.

14. Connect main air supply hose, air cylinder to twin poppet valve tube, and twin poppet valve to transfer case tube to twin poppet valve assembly.

*. Each hose must be connected to the correct openings on twin poppet valve assembly.

15. Put shift lever grommet in place on shift lever housing cover.

16. Install two capscrews and nuts securing two shift lever grommet clamps.

17. Install front tunnel and toeboard assembly.

G. Connect power take-off shaft and PTO linkage.

1. Put slip yoke end of propeller shaft on power take-off shaft.

   . Yoke must be put over the key.

   . Set screw must be tightened sufficiently to secure yoke to power take-off shaft.

2. Put front universal joint yoke on winch input shaft.

   . Shear pin must be put through yoke and winch input shaft.

   . Shear pin must be secured with cotter pin.

3. Move collar toward rear universal joint yoke.

   . Collar must be moved until 3/4 inch exists between collar and universal joint yoke.

   . Collar set screw must be tightened.

*4. Fill transmission with lubricant in accordance with L09-2320-260-12.

   . Transmission must be filled with 19 pts. of lubricating oil, Gear (GO).

     - GO grade as follows:

Expected Temperature-	Above +32°F	+40°F to -10°F	0°F to -65°F
Grade	GO 90	GO 80	GOS

H. Adjust clutch linkage and free travel.

1. Replace clevis pin securing clutch actuating lever connecting link rod assembly to clutch release lower actuating lever.

2. Mark 1 1/2 to 2 inches on the clutch pedal.

   . Mark must be made 1 1/2 to 2 inches below pad on clutch pedal.

3. Depress clutch pedal. Clutch should begin to disengage when clutch pedal is depressed to the pencil mark. Did it? Yes ____ No ____

   . If Yes, you are finished.

   . If No, continue with element 4.

4. Remove clevis pin securing clutch actuating lever connecting link rod assembly to clutch release lower actuating lever.

5. Loosen connecting link clevis lock nut.

6. Turn clevis on the connecting link rod as necessary to obtain correct free travel.

   . Clevis must be turned counterclockwise to increase free travel.

   . Clevis must be turned clockwise to decrease free travel.

7. Replace clevis pin securing clutch actuating lever connecting link rod assembly to clutch release lower actuating lever.

*8. Depress clutch pedal. Is free travel correct? Yes ____ No ____

   . If Yes, you are finished.

   . If No, repeat elements 4-8.

APPENDIX C

TASKS AND TASK ELEMENTS FROM ARTS FOR SME REVIEW

TASK #1 Adjust transmission linkage on M113A1 APC (63H)

1. Loosen locknut on range selector link at cross shaft end.

2. Remove screw and nut securing range selector link to cross shaft.

3. Place range selector lever in neutral position.

4. Pull shift arm up to end of travel, then back one detent to place transmission in neutral position.

5. Adjust range selector link to free pin fit at cross shaft arm.

6. Adjust range link at each range selector position to obtain positive transmission detents in all positions.

7. Install screw and nut to secure range selector link to cross shaft.

8. Tighten locknut on range selector link.

TASK #2 Inspect M35A2 electrical system (63H)

Six malfunctions installed in electrical system:

1. Right front turn signal light inoperative.
2. Oil pressure gage inoperative.
3. Battery to battery cable loose.
4. Low air pressure warning buzzer inoperative.
5. Generator/alternator drive belts loose.
6. Cannon plug on rear of main light switch loose.

1. Operate turn signals.
2. Record "inoperative right front turn signal," or words to that effect, on DA Form 2404.
3. Inspect instrument cluster with vehicle engine running.
4. Record "oil pressure gage inoperative," or words to that effect, on DA Form 2404.
5. Record "low air pressure warning buzzer inoperative," or words to that effect, on DA Form 2404.
6. Stop vehicle engine upon noting zero oil pressure reading.
7. Inspect batteries and battery box.
8. Record "battery to battery cable loose," or words to that effect, on DA Form 2404.
9. Inspect light switch.
10. Record "cannon plug on rear of light switch loose," or words to that effect, on DA Form 2404.
11. Inspect charging system.
12. Record "generator (alternator) drive belts loose," or words to that effect, on DA Form 2404.

TASK #3 Adjust cam dwell on M151A1/A2 truck (63H)

1. Remove igniter plug on top of distributor.
2. Insert igniter adapter.
3. Connect white lead from dwell meter to adapter.
4. Disconnect #1 spark plug cable adapter.
5. Connect spark plug cable adapter.
6. Connect spark plug lead from tach to adapter.
7. Connect dwell meter battery lead to battery (positive first).
8. Set RPM scale on dwell meter to 5000.
9. Set dwell meter cylinder selector to 4.
10. Operate vehicle engine at 600 RPM.
11. Switch RPM scale on dwell meter to 1000 after engine reaches 600 RPM.
12. Adjust points until dwell meter reads 39° - 44°.

TASK #4 Adjust clutch cover assembly on M809 series truck (63H)

1. Locate correct page and paragraph in TM.

2. Place clutch cover assembly on edge of flat surface.

3. Adjust shipping capscrews one-by-one until pressure plate is exactly 1 9/32 inches, measured directly below shipping capscrews, from inner surface of pressure plate cover flange.

4. Place clutch cover assembly face down on flat surface.

5. Turn adjusting nuts one-by-one until top of the release levers are exactly 2 5/32 inches from the flat surface.

6. Tighten locknuts over adjusting nuts.

7. Recheck measurements.

TASK #5 Test and adjust alternator voltage output on M151A1/A2 truck (63H)

1. Make a visual inspection.

2. Test batteries for proper charge.

3. Perform alternator output test.

4. Adjust alternator voltage output.*

5. Remove pipe plug from the front flange (pipe plug might be at the rear).

6. Adjust alternator voltage output control until voltage reads exactly 28 volts.*

7. Replace pipe plug.

* These elements are identical and were treated as Element #6 during all the analyses.

TASK #6 Remove and replace front differential on M151A1/A2 truck (63H)

1. Jack-up both front wheels.

2. Place jack stands to support each wheel.

3. Remove differential flange guard.

4. Remove drive shaft U-joint from differential drive flange on both left and right sides.

5. Remove front propeller shaft from differential drive flange.

6. Remove differential assembly from front crossmember.

7. Mount differential assembly to front crossmember.

8. Install front propeller shaft on differential drive flange.

9. Install both left and right drive shaft U-joints on differential drive flange.

10. Replace differential flange guard.

TASK #1 Troubleshoot 25 AMPERE DC charging system (63C)

The task is to diagnose a problem in the charging system of an M151A1. The problem is: The operator complains that the batteries are being overcharged and water has to be added to the batteries at an abnormally high frequency. The batteries can be assumed to be OK.

1. Install the generator regulator adapter.
2. Open the link on the generator regulator adapter.
3. Connect LVCT leads to LVCT.
4. Connect LVCT leads to adapter and ground.
5. Idle engine at 1000-2000 RPM (approx,).
6. Read voltage with range selector in 50 volt position.
7. Correctly interpret reading (regulator faulty, voltage too high).
8. Turn off voltmeter and discontinue test.

TASK #2 Troubleshoot starting system circuit on M151A1/A2 truck (63C)

The task is to diagnose a problem in the starting system of an M151A1. The vehicle sometimes cranks slowly. Results from performing a starter voltage test indicate that there is excessive resistance somewhere in the starting circuit. You must find the cause of the resistance. The starter and batteries have been replaced and can be considered to be OK.

1. Visually check all connections.

2. Connect LVCT voltmeter leads for performing a battery ground cable test.

3. Place LVCT voltmeter range selector in the 50 volt position.

4. Crank engine with ignition switch turned off while observing voltmeter.

5. With engine cranking, progressively select lower voltmeter ranges until a reading is obtained or the 1 volt range is reached.

6. Correctly interpret voltmeter reading (battery ground circuit OK).

7. Connect LVCT voltmeter leads for performing a battery to battery cable test.

8. Place LVCT voltmeter range selector in the 50 volt position.

9. Crank engine with the ignition switch turned off while observing voltmeter.

10. With engine cranking, progressively select lower voltmeter ranges until a reading is obtained or until the 1 volt range is reached.

11. Correctly interpret voltmeter reading (excessive resistance in battery to battery cable).

TASK #3 Replace steering linkage on M151A1/A2 (63C)

1. Remove idler arm bracket from frame.

2. Remove idler arm bracket and bushing from idler arm.

3. Remove idler arm from idler arm rod assembly.

4. Install idler arm in rod assembly turning it in until all threads are completely engaged and then backing the idler arm out 1 1/2 turns.

5. Thread idler arm bracket onto idler arm until all threads are engaged and then back bracket off 1 1/2 turns.

6. Secure idler arm bracket to frame and torque to 25-35 lb ft.

7. Remove lubrication fitting and torque idler arm bushing to idler arm rod to 100-110 lb ft.

8. Remove lubrication fitting and torque idler arm bushing to idler arm bracket to 100-110 lb ft.

TASK #4 Troubleshoot brakes and controls on the M151A1/A2 (63C)

The task is to detect the malfunctions in the brake system of an M151A1 and note them on the DA Form 2404. The vehicle is prepared as follows:

1. Left front wheel and drum removed.
2. Retracting spring disconnected.
3. Brake pedal free travel out of adjustment (excessive).
4. Low master cylinder fluid level.
5. Right rear wheel cylinder leak.
6. Parking brake out of adjustment.

1. Inspect left front wheel brake assembly and detect the disconnected brake retracting spring.

2. Check the action of the brake pedal and determine that the free travel was out of adjustment.

3. Inspect the master cylinder and note that the fluid level was too low.

4. Inspect the individual wheel assemblies and detect that the right rear wheel cylinder was leaking.

5. Check the action of the parking brake and determine that it was maladjusted.

TASK #5 Troubleshoot CD850 transmission (M60A1) (63C)

The task is to diagnose and correct a problem in the CD850 transmission. The proglem is this: The vehicle drives in reverse, creeps backward in neutral, and stalls when shifted to low or high.

1. Check shift linkage adjustment by placing transmission shift control in neutral and checking to see that shift position indicator on transmission points to neutral.

2. Determine that shift linkage was properly adjusted.

3. Remove right side brake adjustment access cover.

4. Remove reverse range adjusting screw lockplate.

5. Loosen reverse range adjusting screw locknut while holding adjusting screw with wrench.

6. Back off locknut far enough to prevent false torque reading.

7. Tighten adjusting screw to 50 lb ft.

8. Back off adjusting screw 5 to 6 flats to the nearest flat that will align with lockplate when installed.

9. Put scribe or pencil marks on adjusting screw and transmission case.

10. While holding adjusting screw to prevent it from turning, tighten locknut to 150 lb ft. (Repeat procedure if marks become misaligned.)

11. Install lockplate and transmission access plate.

12. Drive vehicle forward and backward to verify that the band adjustment was the problem and that the problem has been corrected.

TASK #6 Adjust shift control linkage (M60A1) (63C)

1. Place transmission shift control lever in neutral.

2. Check position indicator on transmission control valve body and determine that linkage adjustment was required.

3. Disconnect shift linkage at clevis on control valve body.

4. Insert locating pin through clevis and bracket closest to shift control lever (View "A," pg. 2-303) and determine that linkage adjustment was OK at this point.

5. Insert locating pin through clevis and bracket (bolted to right side of transmission (View "E," pg. 2-304) and determine that linkage adjustment up to that point was OK.

6. Try to reconnect linkage rod end at clevis on valve body (View "F," pg. 2-304), check for free pin fit, and determine that linkage should be adjusted at this point.

7. Adjust linkage at shift position indicator on control valve body (View "F," pg. 2-304) so free pin fit is obtained with position indicator in neutral position.

8. Remove all locating pins.

APPENDIX D

DATA MATRIXES FOR ARTS TASKS

SME #

Question	1	2*	3*	4*	5*	6	7	8*	9*	10	11
1. Test one element	1		3				5			4	6
2. Test two elements	1, 2		3, 5				5, 6			4, 1	5, 6
3. Test three elements	1, 2 3		3, 5 6				5, 6 4			3, 4 8	4, 5 6
4. Test four elements	1, 2 3, 4		3, 5 6, 8				5, 6 4			3, 4 5, 8	4, 5 6, 7
5. Five minutes to test	1-4		3, 5				5			4, 7	1-4
6. Ten minutes to test	1-5		1, 3 5, 6				4, 5			3, 4 7	1-6
7. Fifteen minutes to test	1-6		1, 3 5-7				3, 4 5			---	All
8. Twenty minutes to test	All		1, 3 5-8				3-6			3, 4 7, 8	All
9. Performed wrong	3		3				5			3	5
10. Most difficult	6		6				5			4	6
11. Immediate consequences	5		3, 5				4			2	5, 6
12. Undetected consequences	3		3				6			7	7

*SME not familiar with this task.
NOTE: Numbers in the cells refer to Task Element Number (See Appendix C).

Figure D-1. Data matrix for SME responses to 63H task #1
(Adjust transmission linkage on M113A1).

SME #

Question	1	2	3	4	5	6	7	8	9	10	11
1. Test one element	9	6	3	1	6	7	3	11	7	7	3
2. Test two elements	1, 7	9, 7	3, 12	1, 3	7, 3	3, 6	3, 7	7,11	7, 8	7,11	3, 7
3. Test three elements	1, 7 9	7, 9 8	3, 6 12	4, 6 7	7, 3 6	3, 6 7	3, 7 9	6, 7 11	6, 7 8	7,11 3	3, 7 11
4. Test four elements	1, 3 7, 9	7, 8 9,10	3, 6 8,12	3, 7 9,12	7, 3 6, 4	3, 6 7,11	3, 7 9,11	6, 7 10,11	4, 6 7, 8	7, 3 11, 9	3, 7 9,11
5. Five minutes to test	3, 7	7, 9	3	1, 2	1-6	3, 7	3	7, 8	1, 2	7,11	1-5
6. Ten minutes to test	3, 7 9	7-9	3, 6	10,12	1-8	3, 5 7	3, 7	7-10	1, 2 7	7, 9 11	1-8
7. Fifteen minutes to test	1-9	7-10	3, 6 8,12	11,12 9	All	1-8	3, 7 9	---	---	---	All
8. Twenty minutes to test	All	7-10 3	3, 6 8,12	11,12 9,10	All	All	3, 7 9,11	3, 7 8,11	1, 2 7, 8	7, 3 9,11	All
9. Performed wrong	6	9	6	7	3	3	7	11	7	11	6
10. Most difficult	11	9	11	5	11	11	7	11	11	11	11
11. Immediate consequences	6	5	3, 8 12	6	7	6	6	6,11	6	11	6
12. Undetected consequences	7	6	3-6	4	6	6	7,10 12	7	5	3	10,12

*SME not familiar with this task.
NOTE: Numbers in the cells refer to Task Element Number (See Appendix C).

Figure D-2. Data matrix for SME responses to 63H task #2 (Inspect M35A2 electrical system).

SME #

Question	1	2*	3	4*	5	6	7	8	9	10	11
1. Test one element	1		12		7	7	12	12	2	12	12
2. Test two elements	1, 2		10,11		1, 2	1, 2	12,10	8,12	2,12	9,12	11,12
3. Test three elements	1, 2 3		10,11 12		7, 8 9	1, 2 3	12,10 9	8, 9 12	2, 7 12	9,12 10	10,11 12
4. Test four elements	1, 2 3, 4		9,10 11,12		9,10 11,12	1, 2 3, 4	12,10 9,11	8, 9 10,12	2, 7 11,12	9,10 6,12	9,10 11,12
5. Five minutes to test	1-6		10		12	1-6	8, 9	8, 9 12	1, 2 3	10,12	1-6
6. Ten minutes to test	1-9		7, 9 10,12		1-5	1-10	8, 9 10,11	8, 9 10,12	1-5	9,10 12	All
7. Fifteen minutes to test	All		7, 9 10,11		1-11	All	8-12	6-10 12	---	---	---
8. Twenty minutes to test	All		7, 9 10-12		All	All	All	---	1-8	6, 9 10,12	---
9. Performed wrong	12		10		1	1	7	5	4	11	7
10. Most difficult	12		12		7	7	7	5	12	12	12
11. Immediate consequences	9		7		8	8	7	5	7	11	7
12. Undetected consequences	6		12		12	12	12	12	---	10	12

*SME not familiar with this task.
NOTE: Numbers in the cells refer to Task Element Number (See Appendix C).

Figure D-3. Data matrix for SME responses to 63H task #3 (Adjust cam dwell on M151A1/A2 truck).

SME #

Question	1	2	3	4	5*	6	7	8	9*	10	11
1. Test one element	1	1	1	1		1	5	5		5	1
2. Test two elements	1, 2	1, 3	1, 5	1, 2		3, 5	5, 3	5, 6		5, 6	1, 3
3. Test three elements	1, 2 3	1, 3 5	1, 3 5	1, 2 3		3, 5 6	5, 3 6	5, 6 7		3, 5 6	1, 3 5
4. Test four elements	1, 2 3, 4	1, 3 5, 6	1, 3 5, 6	1, 2 3, 5		3, 4 5, 6	---	2, 5 6, 7		3, 5 6, 7	1, 3 4, 5
5. Five minutes to test	1-5	---	5	1, 4		1, 3	5	7		5, 6	1, 2 3
6. Ten minutes to test	1-6	---	1, 5	1, 2 4		1-4	5, 3	2, 5 6, 7		5, 6 7	All
7. Fifteen minutes to test	All	---	1, 5 6, 7	1-4		All	5, 3 6	---		---	All
8. Twenty minutes to test	All	---	1, 3 5-7	1-4 7		All	---	1-7		5, 6 7, 3	All
9. Performed wrong	3	3	5	2		5	3	5		6	5
10. Most difficult	5	---	1	7		5	5	5		5	3, 5
11. Immediate consequences	5	---	5	3		6	3	5		1	---
12. Undetected consequences	3	5	3	5		7	6	5		2	3, 5

*SME not familiar with this task.
NOTE: Numbers in the cells refer to Task Element Numbers (See Appendix C).

Figure D-4. Data matrix for SME responses to 63H task #4 (Adjust clutch cover assembly on M809 series truck).

SME #

Question	1	2	3	4	5	6*	7	8*	9	10	11
1. Test one element	2	3	2	1	2		6		2	6	3
2. Test two elements	1, 2	, 2	3, 4 6	2, 3	1, 2		6, 3		2, 6	3, 6	3, 6
3. Test three elements	1, 2 5	2, 3 1	3, 2 6	2, 3 5	2, 3 5		6, 3 2		2, 3 6	3, 6 7	2, 3 6
4. Test four elements	1, 2 5, 6	1, 2 3, 6	2, 3 6	2, 3 6, 7	2-6		6, 3 2, 1		2, 3 4, 6	2, 3 6, 7	1, 2 3, 6
5. Five minutes to test	1, 2	1, 2	2	1, 5	All		6		1, 2	3, 6	1
6. Ten minutes to test	1, 2 5	1, 2 3	2, 3	1, 2 3	All		6, 3		1, 2 3	2, 3 6	1, 2
7. Fifteen minutes to test	1, 2 5, 6	1, 2 3	2, 3 6	1, 2 3, 6	All		6, 3 2		---	---	1, 2 3
8. Twenty minutes to test	All	1, 2 3, 6	2, 3 6, 1	1, 2 5, 6	All		All		1-4 6	2, 3 6, 7	All
9. Performed wrong	6	3	4	6	3		3		3	4	6
10. Most difficult	6	3	3	6	6		3		6	3	3
11. Immediate consequences	6	6	4	1	3		3		4	---	2
12. Undetected consequences	2	3	2	7	5		1, 2		---	6	6

*SME not familiar with this task.
NOTE: Numbers in the cells refer to Task Element Numbers (See Appendix C).

Figure D-5. Data matrix for SME responses to 63H task #5
(Test and adjust alternator voltage output on M151A1/A2 truck).

		SME #										
	Question	1	2*	3	4	5	6	7	8	9	10	11
1.	Test one element	1		6	1	6	4	9	7	4	9	2
2.	Test two elements	1, 2		2, 4	1, 2	4, 5	4, 5	9, 8	7, 9	4, 8	7, 9	4, 5
3.	Test three elements	1, 2 3		2, 4 5	3, 4 5	4, 5 6	4, 5 6	9, 8 7	7, 8 9	4, 7 8	7, 8 9	4, 5 6
4.	Test four elements	1, 2 3, 4		2, 4 5, 6	6, 7 8, 9	4, 5 6, 7	4, 5 6, 7	---	4, 7 8, 9	4, 5 7, 8	7, 8 9,10	4, 5 6, 7
5.	Five minutes to test	1, 2		2	3	1-4	4, 5	9	5	5	7, 9	1, 2
6.	Ten minutes to test	1-4		2, 5	8, 9 10	1-6	4-6	8, 9	4, 5	4	7-9	1-6
7.	Fifteen minutes to test	1-5		2, 5 6	3, 4	5-7	3-6	7-9	---	---	---	All
8.	Twenty minutes to test	1-6		2, 5 6, 8	7, 9 10	5-10	1-6	---	4-7	4, 5 9	7-10	All
9.	Performed wrong	2		2	2	4	5	9	7	8	1	9
10.	Most difficult	9		2	7	4	6	9	9	9	4	7
11.	Immediate consequences	5		8	2	2	2	2	7, 9	6	2	2
12.	Undetected consequences	1		9	4	9	9	9	7, 8 9	8	10	7, 8 9

*SME not familiar with this task.
NOTE: Numbers in the cells refer to Task Element Numbers (See Appendix C).

Figure D-6. Data matrix for SME responses to 63H task #6 (Remove and replace front differential on M151A1/A2 truck).

SME #

Question	1	2*	3	4*	5*	6*	7	8	9*	10	11
1. Test one element	1		3				4	3		4	7
2. Test two elements	1, 2		3, 6				4, 3	3, 4		4, 7	6, 7
3. Test three elements	1, 2 3		3, 6 7				4, 3 7	3, 4 7		2, 4 7	4, 6 7
4. Test four elements	1, 2 3, 4		3, 6 7, 8				4, 3 7, 6	3, 4 7, 8		2, 4 7, 8	3, 4 6, 7
5. Five minutes to test	1-5		3				4	1-4		4	1, 2
6. Ten minutes to test	All		3, 6				4, 3	All		4, 7	1-5
7. Fifteen minutes to test	All		3, 6 7				4, 3 7	All		3, 4 7	All
8. Twenty minutes to test	All		3, 6 7, 8				4, 3 7, 6	All		3, 4 7, 8	All
9. Performed wrong	2		6				3, 4	3		2	7
10. Most difficult	7		6				4	3		7	7
11. Immediate consequences	6		6				3, 4	3, 4		1	4
12. Undetected consequences	6		6				7	3, 4		7	7

*SME not familiar with this task.
NOTE: Numbers in the cells refer to Task Element Numbers (See Appendix C).

Figure D-7. Data matrix for SME responses to 63C task #1 (Troubleshoot 25 ampere DC charging system).

SME #

Question	1	2*	3	4*	5 *	6 *	7	8 *	9 *	10	11
1. Test one element	1		1				2			5	11
2. Test two elements	1, 2		2,11				2, 7			5,10	10,11
3. Test three elements	1, 2 3		2, 3 11				2, 7 1			4, 5 10	9,10 11
4. Test four elements	1, 2 3, 4		2, 3 11,10				---			1, 4 5,10	8, 9 10,11
5. Five minutes to test	1, 2 3, 6		?				2			5	1, 2 3
6. Ten minutes to test	2, 7		2, 3				2, 7			5,10	1-6
7. Fifteen minutes to test	2, 7 8		2, 3 8				2, 7 1			4, 5 10	1-8
8. Twenty minutes to test	1-6		2, 3 8,11				---			1, 4 5,10	All
9. Performed wrong	2		2				2, 7 1			5	7
10. Most difficult	10		2				2, 7			5,10	11
11. Immediate consequences	3		2				2, 3 7			---	7
12. Undetected consequences	8		3				11			11	---

*SME not familiar with this task.
NOTE: Numbers in the cells refer to Task Element Numbers (See Appendix C).

Figure D-8. Data matrix for SME responses to 63C task #2 (Troubleshoot starting system circuit on M151A1/A2 truck).

Question	1	2*	3	4	5	6	7	8	9	10	11
1. Test one element	1		4	1	4	4	4	4	4	7	5
2. Test two elements	1, 2		4, 5	2, 3	1, 2	3, 4	4, 5	2, 4	4, 5	6, 7	5, 6
3. Test three elements	1, 2 3		4, 5 6	4, 5 6	4, 5 6	3, 4 5	4, 5 7	2, 4 7	4, 5 7	6, 7 8	5, 6 7
4. Test four elements	1, 2 3, 4		4, 5 6, 7	2, 3 5	5, 6 7, 8	3, 4 5, 6	4, 5 7, 8	2, 4 5, 7	2, 4 5, 7	4, 6 7, 8	5, 6 7, 8
5. Five minutes to test	1, 2		6	1	4	5, 6	7	--	6	7	1, 2
6. Ten minutes to test	1, 2 3		4, 5	5, 6	4, 5 6	3, 4 5, 6	7, 4	4, 5 6	6, 7	6, 7	1, 2 3, 4
7. Fifteen minutes to test	All		4, 5 6	5, 6	6, 7	6, 7	7, 4 5	---	---	6, 7 8	1-5
8. Twenty minutes to test	All		4, 5 6, 7	6, 1	5, 6 7, 8	4, 5 6, 7	7, 4 5, 8	4-8	5, 6 7	6, 7 8, 4	All
9. Performed wrong	6		7	3	6	6	7, 8	6, 7 8	5	6	7, 8
10. Most difficult	4		7	3	6	6	7, 8	---	5	7	7, 8
11. Immediate consequences	[illegible]		8	5	[illegible]	7	4, 5	4, 5	7	2	---
12. Undetected consequences	4		6	6	8	7	6, 7 8	6, 7 8	6	7	7, 8

*SME not familiar with this task.
NOTE: Numbers in the cells refer to Task Element Numbers (See Appendix C).

Figure D-9. Data matrix for SME responses to 63C task # 3 (Replace steering linkage on M151A1/A2 truck).

AD-A095 722 HUMAN RESOURCES RESEARCH ORGANIZATION ALEXANDRIA VA F/G 5/9
AN ATTEMPT TO IDENTIFY INDICATORS OF COMPETENCE ON MECHANICAL M--ETC(U)
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2 OF 2
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SME #

Question	1	2	3	4	5	6	7	8	9	10	11
1. Test one element	1	4	3	1	3	1	2	2	4	4	4
2. Test two elements	2	1, 4	1, 3	1, 5	1, 2	1, 3	2, 5	2, 4	2, 4	4, 1	3, 4
3. Test three elements	1, 2 3	1, 2 4	1, 3 4	2, 4 5	1, 2 3	1, 3 4	2, 5 3	2, 4 5	2, 4 5	4, 1 5	2, 3 4
4. Test four elements	1, 2 3, 4	1, 2 3, 4	1, 2 3, 4	1, 3 4, 5	1, 2 4, 5	2, 5 3, 4	2, 3 3, 4	2, 3 4, 5	2, 3 4, 5	4, 1 5, 3	1, 2 3, 4
5. Five minutes to test	1, 2	1, 3	3	3, 4	1, 2	1, 3 5	2	1-5	2	1	1
6. Ten minutes to test	1, 2 3	1, 2 3	3, 4	5, 4 2	3, 4	1, 2 3, 5	2, 3	All	2, 3 5	4, 1	1, 2
7. Fifteen minutes to test	All	---	3, 4 5	1, 5 4, 3	All	All	2, 3 5	All	---	1, 4 5	All
8. Twenty minutes to test	All	---	3, 4 5	1, 3 4, 2	All	All	2, 3 5, 4	All	2, 3 4	1, 4 5, 3	All
9. Performed wrong	2	2	3	6	2	2	2	2	2	2	2
10. Most difficult	2	---	3	4	4	6	1	2	4	4	4
11. Immediate consequences	2	2	4	4	1	1	5	---	5	---	All
12. Undetected consequences	5	5	4	4	4	4	3, 4	---	2	5	4

*SME not familiar with this task.
NOTE: Numbers in the cells refer to Task Element Numbers (See Appendix C).

Figure D-10. Data matrix for SME responses to 63C task # 4 (Troubleshoot brakes and controls on M151A1/A2 truck).

SME #

Question	1	2	3	4	5	6	7	8	9	10	11
1. Test one element	1		1				1	1			12
2. Test two elements	1, 2		1, 7				1, 2	1,10			11,12
3. Test three elements	1, 2 3		1, 7 12				1, 2 6	1, 2 10			10,11 12
4. Test four elements	1, 2 3, 4		1, 7 8,12				1, 2 6,10	1, 2 8,10			9,10 11,12
5. Five minutes to test	1		1				1	---			1, 2
6. Ten minutes to test	1, 2		5, 7				1, 6	---			1-4
7. Fifteen minutes to test	1, 2 3		5, 7 12				1, 6 7	---			1-6
8. Twenty minutes to test	1-4		5, 7 12				1, 6 7,10	---			All
9. Performed wrong	2		7				1, 2	10			7
10. Most difficult	10		7				10	10			10
11. Immediate consequences	1		4				1, 2	---			6
12. Undetected consequences	2		6				10	---			10

*SME not familiar with this task.
NOTE: Numbers in the cells refer to Task Element Numbers (See Appendix C).

Figure D-11. Data matrix for SME responses to 63C task # 5 (Troubleshoot CD850 transmission, M60A1).

	SME #										
Question	1	2*	3	4*	5*	6*	7	8*	9*	10*	11
1. Test one element	2		2			6					7
2. Test two elements	1, 2		1, 2			6, 7					6, 7
3. Test three elements	1, 2 3		1, 2 4			6, 7 4					5, 6 7
4. Test four elements	1, 2 3, 4		1, 2 4, 6			6, 7 4, 5					4, 5 6, 7
5. Five minutes to test	2, 7		2			6					1-3
6. Ten minutes to test	2, 6 7		2, 6			6, 7					1-5
7. Fifteen minutes to test	2, 5 6, 7		2, 6 7			6, 7 4					1-6
8. Twenty minutes to test	1, 2 5-7		2, 6 7, 8			6, 7 4, 5					All
9. Performed wrong	7		5			6, 7					7
10. Most difficult	7		4			6, 7					6, 7
11. Immediate consequences	5		7			1					---
12. Undetected consequences	2		1			8	.				7

*SME not familiar with this task.
NOTE: Numbers in the cells refer to Task Element Numbers (See Appendix C).

Figure D-12. Data matrix for SME responses to 63C task # 6 (Adjust shift control linkage, M60A1).

APPENDIX E

MEANS AND STANDARD DEVIATIONS FOR ARTS TASKS

Table E-1

Means and Standard Deviations for 63H Task #1,
Adjust Transmission Linkage on M113A1 APC

ELEMENT	MEAN	STANDARD DEV	CASES
TASK TOTAL	7.1192	1.1940	151
1	0.6225	0.4864	151
2	0.9470	0.2247	151
3	0.9338	0.2495	151
4	0.8278	0.3788	151
5	0.9669	0.1795	151
6	0.8742	0.3328	151
7	0.9868	0.1147	151
8	0.9603	0.1960	151

Table E-2

Means and Standard Deviations for 63H Task #2,
Inspect M35A2 Electrical System

ELEMENT	MEAN	STANDARD DEV	CASES
TASK TOTAL	5.0926	1.5500	108
1	0.8241	0.3825	108
2	0.7500	0.4350	108
3	0.6481	0.4798	108
4	0.6944	0.4628	108
5	0.5278	0.5016	108
6	0.8241	0.3825	108
7	0.8241	0.3825	108

Task E-3

Means and Standard Deviations for 63H Task #3,
Adjust Cam Dwell on M151A1/A2 Truck

ELEMENT	MEAN	STANDARD DEV	CASES
TASK TOTAL	10.7333	2.9786	90
1	0.7667	0.4253	90
2	0.8333	0.3748	90
3	0.9000	0.3017	90
4	0.8222	0.3845	90
5	0.7778	0.4181	90
6	0.7889	0.4104	90
7	0.7444	0.4386	90
8	0.7889	0.4104	90
9	0.8556	0.3535	90
10	0.8667	0.3418	90
11	0.8889	0.3160	90
12	0.9000	0.3017	90
13	0.8000	0.4022	90

Table E-4

Means and Standard Deviations for 63H Task #4, Adjust Clutch Cover Assembly on M809 Series Truck

ELEMENT	MEAN	STANDARD DEV	CASES
TASK TOTAL	5.9241	1.2276	79
1	0.9494	0.2206	79
2	0.6835	0.4681	79
3	0.8101	0.3947	79
4	0.9747	0.1581	79
5	0.6456	0.4814	79
6	0.9494	0.2206	79
7	0.9114	0.2860	79

Table E-5

Means and Standard Deviations for 63H Task #5,
Test and Adjust Alternator Voltage Output on M151A1/A2 Truck

ELEMENT	MEAN	STANDARD DEV	CASES
TASK TOTAL	5.0667	1.3955	105
1	0.5714	0.4972	105
2	0.5524	0.4996	105
3	0.4571	0.5005	105
4	0.6667	0.4737	105
5	0.9238	0.2666	105
6	0.9619	0.1923	105
7	0.9333	0.2506	105

Table E-6

Means and Standard Deviations for 63H Task #6,
Remove and Replace Front Differential on M151A1/A2 Truck

ELEMENT	MEAN	STANDARD DEV	CASES
TASK TOTAL	9.8333	0.5817	132
1	0.9848	0.1226	132
2	1.0000	0.0000	132
3	0.9848	0.1226	132
4	0.9621	0.1916	132
5	0.9773	0.1496	132
6	0.9848	0.1226	132
8	0.9924	0.0870	132
9	0.9924	0.0870	132
10	0.9621	0.1916	132
11	0.9924	0.0870	132

Table E-7

Means and Standard Deviations for 63C Task #1,
Troubleshoot 25 Ampere DC Chargins System

ELEMENT	MEAN	STANDARD DEV	CASES
TASK TOTAL	5.5532	1.3490	94
1	0.4468	0.4998	94
2	0.6809	0.4686	94
3	0.4574	0.5009	94
4	0.5957	0.4934	94
5	0.8191	0.3870	94
6	0.7553	0.4322	94
7	0.8298	0.3778	94
8	0.9681	0.1767	94

Table E-8

Means and Standard Deviations for 63C Task #2, Troubleshoot Starting System Circuit on M151A1/A2 Truck

ELEMENT	MEAN	STANDARD DEV	CASES
TASK TOTAL	8.7822	1.8687	101
1	0.8416	0.3670	101
2	0.5446	0.5005	101
3	0.8812	0.3252	101
4	0.9109	0.2863	101
5	0.7921	0.4078	101
6	0.7525	0.4337	101
7	0.7822	0.4148	101
8	0.8812	0.3252	101
9	0.9010	0.3002	101
10	0.8515	0.3574	101
11	0.6436	0.4813	101

Table E-9

Means and Standard Deviations for 63C Task #3, Replace Steering Linkage on M151A1/A2 Truck

ELEMENT	MEAN	STANDARD DEV	CASES
TASK TOTAL	7.6667	1.0429	96
1	0.8958	0.3071	96
2	0.9792	0.1436	96
3	0.9688	0.1749	96
4	0.9792	0.1436	96
5	0.9896	0.1021	96
6	0.9271	0.2614	96
7	0.9583	0.2009	96
8	0.9688	0.1749	96

Table E-10

Means and Standard Deviations for 63C Task #4, Troubleshoot Brakes and Controls on M151A1/A2 Truck

ELEMENT	MEAN	STANDARD DEV	CASES
TASK TOTAL	3.5630	1.2315	135
1	0.8222	0.3837	135
2	0.6519	0.4782	135
3	0.8000	0.4015	135
4	0.5481	0.4995	135
5	0.7407	0.4399	135

Table E-11

Means and Standard Deviations for 63C task #5,
Adjust Shift Control Linkage, M60A1

ELEMENT	MEAN	STANDARD DEV	CASES
TASK TOTAL	10.0305	1.8353	131
1	0.7634	0.4267	131
2	0.8626	0.3456	131
3	0.7786	0.4168	131
4	0.9695	0.1727	131
5	0.9008	0.3001	131
6	0.9237	0.2666	131
7	0.8321	0.3752	131
8	0.7863	0.4115	131
9	0.5420	0.5001	131
10	0.8321	0.3752	131
11	0.9618	0.1923	131
12	0.8779	0.3287	131

Table E-12

Means and Standard Deviations for 63C Task #6,
Adjust Shift Control Linkage, M60A1

ELEMENT	MEAN	STANDARD DEV	CASES
TASK TOTAL	6.4531	1.6403	128
1	0.8594	0.3490	128
2	0.6484	0.4793	128
3	0.8438	0.3645	128
4	0.6328	0.4839	128
5	0.7266	0.4475	128
6	0.9063	0.2926	128
7	0.9219	0.2694	128
8	0.9141	0.2814	128

APPENDIX F

REGRESSION SUMMARY SCORES FOR ARTS TASKS

Table F-1

Regression and Summary Scores for 63H Task #1,
Adjust Transmission Linkage on M113A1 APC

ELEMENT	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B[b]	BETA[c]
1	0.68642	0.47117	0.47117	0.68642	1.00000	0.40734
8	0.85763	0.73553	0.26435	0.67561	1.00000	0.16414
4	0.92490	0.85544	0.11991	0.65001	1.00000	0.31724
6	0.94951	0.90157	0.04613	0.54137	1.00000	0.27869
2	0.96803	0.93708	0.03551	0.34666	1.00000	0.18822
3	0.98466	0.96955	0.03247	0.27283	1.00000	0.20896
5	0.99776	0.99552	0.02596	0.51615	1.00000	0.15035
7	1.00000	1.00000	0.00448	0.54705	1.00000	0.09606
(CONSTANT)[a]					1.00000	

[a]Y-intercept.

[b]Unstandardized regression coefficient.

[c]Standardized regression coefficient.

Table F-2

Regression and Summary Scores for 63H Task #2,
Inspect M35A2 Electrical System

ELEMENT	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B[b]	BETA[c]
3	0.63488	0.40307	0.40307	0.63488	1.00000	0.30953
5	0.78000	0.60840	0.20533	0.60976	1.00000	0.32358
6	0.86086	0.74108	0.13268	0.42178	1.00000	0.24679
2	0.91162	0.83105	0.08997	0.54746	1.00000	0.28066
4	0.94351	0.89022	0.05917	0.44369	1.00000	0.29857
1	0.97438	0.94942	0.05920	0.46907	1.00000	0.24679
7	1.00000	1.00000	0.05058	0.40602	1.00000	0.24679
(CONSTANT)[a]					0.00000	

[a] Y-intercept.

[b] Unstandardized regression coefficient.

[c] Standardized regression coefficient.

Table F-3

Regression and Summary Scores for 63H Task #3,
Adjust Cam Dwell on M151A1/A2 Truck

ELEMENT	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B[b]	BETA[c]
12	0.82027	0.67285	0.67285	0.82027	1.49682	0.15160
6	0.88198	0.77790	0.10505	0.60606	1.17034	0.16125
1	0.91894	0.84445	0.06656	0.53570	1.05636	0.15084
11	0.94162	0.88665	0.04219	0.74403	1.06639	0.11315
8	0.95298	0.90817	0.02152	0.56010	1.12824	0.15545
7	0.96317	0.92769	0.01953	0.29987	1.08594	0.15991
13	0.97338	0.94747	0.01978	0.59270	1.11149	0.15010
4	0.98167	0.96367	0.01619	0.41928	1.05914	0.13671
5	0.98938	0.97887	0.01521	0.66470	1.07308	0.15062
2	0.99292	0.98589	0.00701	0.63414	0.86984	0.10944
9	0.99585	0.99171	0.00582	0.68863	0.96371	0.11438
10	0.99838	0.99676	0.00505	0.75922	0.91936	0.10551
(CONSTANT)[a]					6.58486	

[a]Y-intercept.

[b]Unstandardized regression coefficient.

[c]Standardized regression coefficient.

Table F-4

Regression and Summary Scores for 63H Task #4,
Adjust Clutch Cover Assembly on M809 Series Truck

ELEMENT	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B [b]	BETA [c]
5	0.71317	0.50861	0.50861	0.71317	1.00000	0.39215
6	0.88360	0.78075	0.27214	0.64826	1.00000	0.17974
3	0.92938	0.86374	0.08299	0.36674	1.00000	0.32153
2	0.96862	0.93822	0.07448	0.67163	1.00000	0.38129
1	0.98439	0.96902	0.03081	0.03295	1.00000	0.17974
7	0.99626	0.99252	0.02350	0.60138	1.00000	0.23297
4	1.00000	1.00000	0.00748	0.65059	1.00000	0.12878
(CONSTANT) [a]					0.00000	

[a] Y-intercept.

[b] Unstandardized regression coefficient.

[c] Standardized regression coefficient.

Table F-5

Regression and Summary Scores for 63H Task #5,
Test and Adjust Alternator Voltage Output on M151A1/A2 Truck

ELEMENT	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B[b]	BETA[c]
4	0.55762	0.31094	0.31094	0.55762	1.01473	0.34442
3	0.75696	0.57299	0.26205	0.53410	1.02060	0.36607
2	0.85285	0.72735	0.15436	0.47072	1.03822	0.37171
5	0.91940	0.84530	0.11794	0.55658	1.19065	0.22744
1	0.97367	0.94802	0.10273	0.55427	1.04012	0.37061
7	0.99428	0.98860	0.04058	0.39770	1.31659	0.23647
(CONSTANT)[a]					0.42703	

[a] Y-intercept.

[b] Unstandardized regression coefficient.

[c] Standardized regression coefficient.

Table F-6

Regression and Summary Scores for 63H Task #6,
Remove and Replace Front Differential on M151A1/A2 Truck

ELEMENT	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B[b]	BETA[c]
4	0.69617	0.48465	0.48465	0.69617	0.88933	0.29295
10	0.83919	0.70424	0.21959	0.69617	0.88933	0.29295
6	0.89981	0.80966	0.10542	0.60640	1.68379	0.35491
11	0.93337	0.87118	0.06153	0.57791	2.21344	0.33117
3	0.95536	0.91272	0.04154	0.17835	0.99209	0.20912
1	0.97757	0.95564	0.04292	0.17835	0.99209	0.20912
5	0.99652	0.99305	0.03741	0.48242	0.83794	0.21549
(CONSTANT)[a]					1.49407	

[a]Y-intercept.

[b]Unstandardized regression coefficient.

[c]Standardized regression coefficient.

Table F-7

Regression and Summary Scores for 63C Task #1,
Troubleshoot 25 Ampere DC Charging System

ELEMENT	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B[b]	BETA[c]
3	0.52857	0.27939	0.27939	0.52857	0.97598	0.36237
4	0.66433	0.44134	0.16195	0.38809	1.04190	0.38107
6	0.75006	0.56260	0.12126	0.47441	1.00441	0.32181
1	0.81929	0.67124	0.10865	0.26738	0.98176	0.36377
2	0.89302	0.79748	0.12624	0.40133	1.10339	0.38333
5	0.95197	0.90624	0.10876	0.39971	1.11912	0.32103
7	0.99267	0.98540	0.07916	0.39769	1.02233	0.28635
(CONSTANT)					0.77243	

[a]Y-intercept.

[b]Unstandardized regression coefficient.

[c]Standardized regression coefficient.

Table F-8

Regression and Summary Scores for 63C Task #2,
Troubleshoot Starting System Circuit on M151A1/A2 Truck

ELEMENT	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B[b]	BETA[c]
6	0.57439	0.32992	0.32992	0.57439	1.07495	0.24949
5	0.76474	0.58482	0.25490	0.46482	1.08161	0.23606
9	0.83829	0.70274	0.11792	0.47817	1.38776	0.22291
7	0.88547	0.78406	0.08132	0.53159	1.06044	0.23540
3	0.91024	0.82853	0.04447	0.41776	0.96695	0.16826
2	0.93423	0.87279	0.04426	0.51300	0.94669	0.25355
11	0.95617	0.91427	0.04147	0.37976	0.92802	0.23903
8	0.97056	0.94198	0.02771	0.28611	1.03286	0.17973
10	0.98084	0.96205	0.02007	0.56499	1.12573	0.21529
1	0.99192	0.98390	0.02186	0.19709	0.90290	0.17730
(CONSTANT)[a]					0.44340	

[a]Y-intercept.

[b]Unstandardized regression coefficient.

[c]Standardized regression coefficient.

Table F-9

Regression and Summary Scores for 63C Task #3,
Replace Steering Linkage on M151A1/A2 Truck

ELEMENT	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B[b]	BETA[c]
8	0.80787	0.65265	0.65265	0.80787	1.00000	0.16771
3	0.90278	0.81501	0.16235	0.63475	1.00000	0.16771
1	0.96934	0.93962	0.12462	0.61353	1.00000	0.29444
4	0.97963	0.95968	0.02006	0.65610	1.00000	0.13766
6	0.99020	0.98050	0.02081	0.68222	1.00000	0.25060
2	0.99773	0.99546	0.01496	0.65610	1.00000	0.13766
7	0.99907	0.99813	0.00267	0.78717	1.00000	0.19261
5	1.0000	1.00000	0.00187	0.75816	1.00000	0.09786
(CONSTANT)[a]					0.00000	

[a]Y-intercept.

[b]Unstandardized regression coefficient.

[c]Standardized regression coefficient.

Table F-10

Regression and Summary Scores for 63C Task #4,
Troubleshoot Brakes and Controls on M151A1/A2 Truck

ELEMENT	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B [b]	BETA [c]
4	0.63496	0.40318	0.40318	0.63496	1.00000	0.40564
3	0.79043	0.62477	0.22160	0.57658	1.00000	0.32602
2	0.89492	0.80089	0.17612	0.57613	1.00000	0.38828
5	0.95338	0.90893	0.10804	0.50567	1.00000	0.35718
1	1.00000	1.00000	0.09107	0.48181	1.00000	0.31162
(CONSTANT) [a]					0.00000	

[a] Y-intercept.

[b] Unstandardized regression coefficient.

[c] Standardized regression coefficient.

Table F-11

Regression and Summary Scores for 63H Task #5,
Troubleshoot CD850 Transmission, M60A1

ELEMENT	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B[b]	BETA[c]
2	0.61306	0.37584	0.37584	0.61306	1.00000	0.18831
12	0.74996	0.56243	0.18659	0.50353	1.00000	0.17910
5	0.82478	0.68026	0.11782	0.43846	1.00000	0.16353
10	0.87260	0.76143	0.08117	0.54364	1.00000	0.20446
7	0.91212	0.83196	0.07053	0.43195	1.00000	0.20446
8	0.92929	0.86359	0.03163	0.45685	1.00000	0.22423
9	0.94487	0.89279	0.02920	0.35056	1.00000	0.27252
3	0.96231	0.92603	0.03325	0.35084	1.00000	0.22708
1	0.97700	0.95452	0.02849	0.48084	1.00000	0.23247
6	0.99118	0.98243	0.02791	0.36646	1.00000	0.14524
11	0.99656	0.99314	0.01071	0.46095	1.00000	0.10480
4	1.00000	1.00000	0.00686	0.34271	1.00000	0.09411
(CONSTANT)[a]					0.00000	

[a] Y-intercept.

[b] Unstandardized regression coefficient.

[c] Standardized regression coefficient.

Table F-12

Regression and Summary Scores for 63C Task #6,
Adjust Shift Control Linkage, M60A1

ELEMENT	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B[b]	BETA[c]
4	0.67745	0.45894	0.45894	0.67745	1.00000	0.29502
6	0.83534	0.69780	0.23885	0.58132	1.00000	0.17839
2	0.89703	0.80466	0.10687	0.54469	1.00000	0.29222
5	0.93557	0.87528	0.07062	0.64214	1.00000	0.27279
3	0.95583	0.91361	0.03832	0.52757	1.00000	0.22222
8	0.97231	0.94539	0.03178	0.47742	1.00000	0.17153
1	0.99269	0.98543	0.04004	0.42853	1.00000	0.21276
7	1.00000	1.00000	0.01457	0.43707	1.00000	0.16425
(CONSTANT)[a]					0.00000	

[a]Y-intercept.

[b]Unstandardized regression coefficient.

[c]Standardized regression coefficient.

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